Sky and TELESCOPE

APR 30 1952
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LEON CAMPBELL

ON THE MORNING of Thursday, May 10, 1951, Leon Campbell died in his native city of Cambridge, Mass., at the age of 71, after a lingering illness. He was a member of the staff of Harvard College Observatory for half a century, and for 25 years was known all over the world as recorder of the American Association of Variable Star Observers.

In June, 1898, he graduated from Cambridge High School, and shortly afterward went to work at Harvard Observatory as an assistant to Professor O. C. Wendell at the 15-inch refractor, which had then itself been in operation for 50 years. For four years, beginning in 1911, Mr. Campbell lived in Arequipa, Peru, in charge of the Harvard southern station there; this station has since been moved to South Africa.

Long-period variables were the first astronomical objects that Assistant Campbell observed at Harvard, and up to his last day at the observatory — two years after his formal retirement — these stars continued to occupy and intrigue him. This story has already been adequately written by one of Mr. Campbell's long-time associates in astronomy, Margaret Harwood, now director of the Maria Mitchell Observatory on Nantucket Island. It was published in *Sky and Telescope* for June, 1949, at the time of Mr. Campbell's 50th anniversary celebration and his retirement.

Mr. Campbell, as AAVSO recorder, received from amateur and professional astronomers their visual observations of the brightnesses of chiefly long-period variable stars. As there are hundreds of such stars in the sky, the professional astronomers cannot keep satisfactory track of their light fluctuations. Under Mr. Campbell's guidance, the AAVSO observers have built up a total of more than a million observations over the past few decades. The 40th anniversary of the association will be celebrated in October of this year, but without Leon Campbell, who was present at every annual meeting after his return from Peru in 1915.

Harvard University honored him twice, in 1934 with membership in the Society of the Sigma Xi; in June, 1949, with an honorary master of arts degree.

For many years, Mr. Campbell conducted all of the open nights at Harvard Observatory. School children's open nights were held on every other Friday throughout the school year; these were attended by students from grade schools, high schools, and colleges. In this way, he brought glimpses of astronomy to literally thousands of people every year.

The inestimable service that Leon Campbell rendered astronomy was his

(Continued on page 230)

Sky and TELESCOPE

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LETTERS

Sir:

Referring to Sidney I. Scheuer's inquiry concerning the names of certain stars in Gemini, page 26, **Sky and Telescope,** December, 1950:

Propus, to my knowledge, is the only star name (of those concerned) derived directly from the catalogue of Hipparchus. Both Geminus and Hyginus, who flourished in the 1st century B.C., are responsible for its appearing in the literature of the constellations.

Ptolemy's descriptions of the three stars involved follow. **Eta:** "the one at the projecting foot of the foremost twin"; **Mu:** "the one following this at the same foot"; **1 Geminorum:** "the one preceding the projecting foot of the foremost twin." Ptolemy, therefore, placed Eta and Mu on Castor's left foot and 1 Geminorum in front of it. It must be remembered that Ptolemy assigned very few proper names to the stars, and, in this case, he never intended the word "propous" to be the proper name of any star: it simply described the position of the foot.

The name, therefore, should be applied to Eta, as being the first star, in order of right ascension, in Castor's left foot, and the first one mentioned by Ptolemy.

In the case of **Tejat,** we have an entirely different situation. This is a corrupt form of a perfectly good Arabic word, the plural of which was applied to three stars in the feet of Castor, and was intended to describe a certain phenomenon connected with the cosmical setting of those three stars. The name Tejat apparently appeared in the astronomical literature and on star charts between the years 1809 and 1843. In the latter year we find it on Burritt's charts, Plate III. Ideler does not mention it.

As-Sufi, our most ancient Arabic authority, says that **"eta, mu,** and **nu,** which are in the feet of the foremost twin, are called **at-Tahayi."** This is the plural of **at-Tahyat,** of which **Tejat** is the corrupt form. The lexicons state that **at-Tahayi** is derived from **al-Haya,** "the rain," and that the asterism was so named because its **Nau',** or cosmical setting, was attended by much rain. **At-Tahayi,** therefore, means "the rain-bearers," and the singular, corresponding to **Tejat** (omitting the article), means "rain-bearer."

Following the usual custom of naming individual stars from Arabian asterisms, the name **Tejat** should be applied to Mu, which is normally the brightest of the three stars.

GEORGE A. DAVIS, JR.
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VOL. X, NO. 9
WHOLE NUMBER 117

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BACK COVER: The galactic cluster NGC 4755 (κ Crucis), photographed with the 60-inch Rockefeller reflector of Harvard's Boyden station, exposure 45 minutes on Eastman 103a-O emulsion. Harvard Observatory photograph. (See page 211.)

SKY AND TELESCOPE is published monthly by Sky Publishing Corporation, Harvard College Observatory, Cambridge 38, Mass. Entered as second class matter, April 28, 1939, at the Post Office, Boston, Mass., under Act of March 3, 1879; accepted for mailing at the special rate of postage provided in Paragraph 4, Section 538, Postal Laws and Regulations.

Subscriptions: $4.00 per year in the United States and possessions, and to Latin-American countries; $7.00 for two years. Add $1.00 per year for Canada and for all other foreign countries, making the total subscription $5.00 per year and $9.00 for two years. Canadian and foreign remittances should be made in United States currency. Single copies, 35 cents. Circulation staff: Betty G. Dodd, manager; Nancy R. Bolton; Virginia K. McAuliffe.

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Editorial and advertising offices: Harvard College Observatory, Cambridge 38, Mass. Unsolicited articles and pictures are welcome, bearing adequate return postage, but we cannot guarantee prompt editorial attention, nor are we responsible for the return of unsolicited manuscripts.

Dynamics and Evolution of Star Clusters--I

By Bart J. Bok, *Boyden Station of Harvard College Observatory*

THE presence in our Milky Way system of 100 observable globular clusters and at least four times as many galactic (or open) clusters offers a constant challenge to the galactic investigator who interests himself in the problems of the dynamics and evolution of the system and its constituent parts. Star clusters can hardly be permanent and unchanging objects. What holds them together and what prevents them either from collapsing or from disintegrating? They must be undergoing gradual changes of a predictable sort. From a study of their likely future developments, one may at least endeavor to guess at their probable pasts. What are the rates at which they will develop? Are they gradually disappearing from the galactic scene, or can we count on having the supply replenished by new star clusters as the old ones disappear? These are questions of a fundamental nature. By attempting to answer them we should not only learn much about star clusters and their evolution, but we may incidentally throw some light on the larger problem of the evolution of the Milky Way system.

Forces Acting upon a Cluster

The study of the dynamics of a star cluster deals with the effects of various forces influencing the motions of the individual stars that make up the star cluster. These forces may be grouped as follows:

1. Forces exerted by the attraction of the star cluster as a whole upon each component member.

2. Forces exerted by the Milky Way system as a whole upon the cluster and its member stars; what concerns us especially are the *differences* between the galactic force of attraction upon individual stars and the average for the entire cluster.

3. Fluctuating forces produced by the attraction between two member stars of the cluster that happen to pass close by each other.

4. Fluctuating forces produced by the passage of galactic field stars through or close to the cluster.

We shall examine these forces and their effects one by one, but, before we can do so, we must have some information regarding the amount and nature of each force. We are at first concerned primarily with the forces listed under (1) and (2) above.

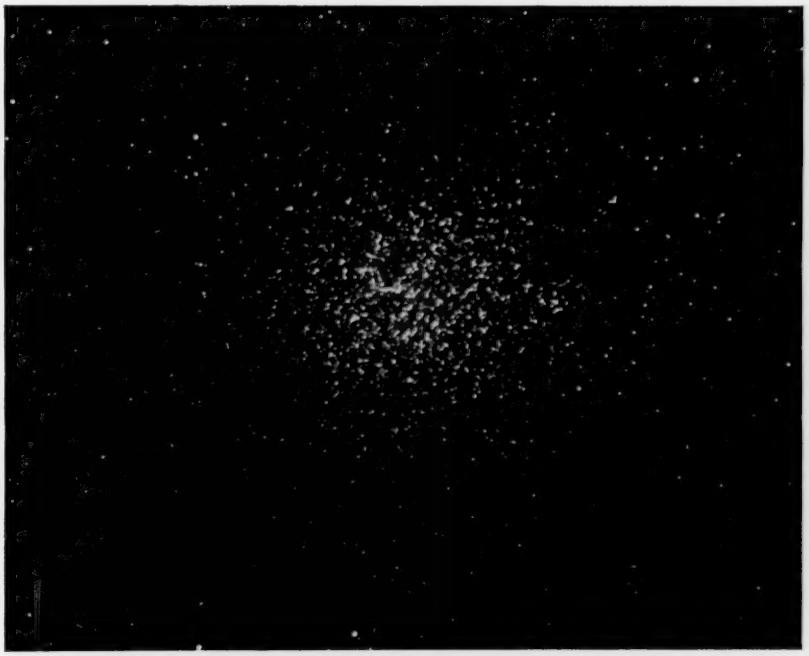
The attraction of a cluster as a whole upon each member can be calculated if we know the dimensions of the cluster, its total star population, and the distribution of the member stars inside the cluster. Here we must differentiate sharply between galactic and globular clusters. A typical galactic cluster, such as the Pleiades, has a total mass approximately 400 times that of our sun and a radius of about eight light-years. For an average globular cluster, the radius is more nearly 50 light-years, but the total mass may exceed that of a galactic cluster by a factor of 1,000, or more! Whereas in the Pleiades we shall probably find, on the average, one star like our sun per five cubic light-years, the corresponding density of stars in a typical globular cluster (in spite of the larger radius) will be of the order of 10 times that in the Pleiades.

Stability Considerations

A globular star cluster or a rich galactic cluster is in all likelihood a rather permanent configuration of stars. The motion of the cluster as a unit through our Milky Way system is, of course, controlled by the attraction of the whole of the galaxy, especially the forces produced by the central parts of the galaxy. But when one studies the motions of the stars in a globular cluster relative to each other, he finds that the internal attractive forces are far more important than the differences among the general galactic forces for different points in the cluster.

On the other hand, a thinly populated and very extended galactic cluster will exert relatively small attractive forces upon its own members, and the disruptive tidal forces of the galaxy may for a loose cluster often be considerably larger than the attraction produced by the cluster itself. The dense and massive cluster has a fair chance of being a continuing galactic phenomenon, whereas the star-poor extended cluster will almost surely disintegrate and become lost in the general galactic field. Where is the dividing line between stable and unstable star clusters?

Problems of stability of star clusters can be dealt with on a purely mathematical basis. We can write down the differential equations of motion for a star in the cluster, and deduce under what conditions the cluster stars will oscillate back and forth with respect to the center of the cluster (a stable cluster) and under what conditions the stars will move gradually farther and farther away from the common center, which would indicate a cluster in the process of disintegration. This mathematical problem has been treated by a number of astronomers, including the present writer, and the mathematician will find an excellent summary in the volume, *Principles of Stellar Dynamics,* by S. Chandrasekhar (University of Chicago Press, 1942). But fortunately we can



This short-exposure photograph reveals the inner structure of the famous southern globular cluster Omega Centauri. It was taken with the 60-inch Rockefeller reflector at Harvard's southern station by M. J. Bester.

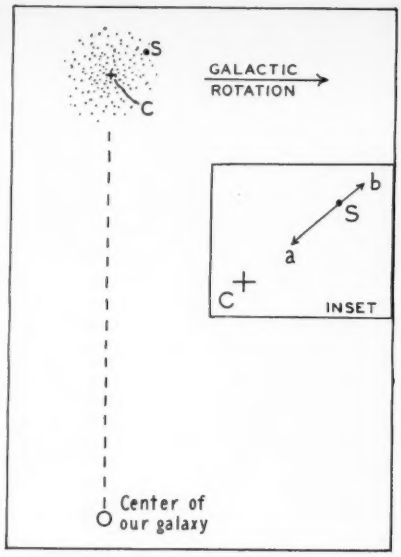
The present article is based on the Rubbi lecture delivered at the University of Stellenbosch on July 28, 1950.

present the nature of the problem and an approximate solution by ignoring the heavy mathematics and replacing it by a simple diagram.

The simplified treatment has a distinguished historical background: It was employed during the 19th century by Schiaparelli in research on the disintegration of comets. The problem of the dissolution of a comet head under the influence of the sun's attraction has very much in common with the problems of cluster disintegration.

In the diagram, *S* represents a star in the cluster and the cross at *C* marks the center of the cluster. The principal forces that control the motion of star *S* are the attraction of the cluster as a whole upon the star, represented by the force vector *a* in the enlarged inset diagram, and the *difference* in the attractive force exerted by our galaxy at *C* (which controls the average motion of the cluster) and the attraction actually exerted at *S*. A little consideration shows that this second force vector *b* will point approximately along the line *SC* in a direction *away from C*, that is, opposite to the direction of force vector *a*. It is clear from the diagram that *a* tends to hold the cluster together, whereas *b* is in the nature of a tidal force and tends to disrupt the cluster. Who will win in this tug of war? If *a* is the larger of the two, stability may occur, but if *b* wins out over *a*, disruption will almost surely follow.

It is not difficult to understand that the principal controlling factor is going to be the average mass density in the cluster. For simplicity, and since our arguments are only qualitative ones anyhow, let us consider the case of a cluster of constant star density. For a given star density the mass of the cluster will be proportional to R^3, if R is the radius of the cluster. But since the cluster attracts star *S* with a force that is *directly proportional* to the mass of the cluster within the distance from star *S* to the center of the cluster and *inversely proportional* to the square of the distance of *S* from the center *C*, the attractive force will, for a given star density, vary as R^3 divided by R^2, that is, it will be proportional to R. Force *b*, on the other hand, has nothing to do with the cluster and depends wholly on the mass distribution and dimensions of our galactic system. But since *b* represents the vector difference between the galactic forces at *S* and at *C*, its amount will be to a first approximation directly proportional to the distance *SC*, that is, to R. In other words, if, in a cluster of constant star density, at any point force *a* is larger than force *b*, the same condition will hold throughout the cluster and vice versa. Hence, our simple argument shows that the star density in the cluster is the principal controlling factor in stability considerations.



A schematic representation of the simplified problem of the forces acting on a cluster in the galaxy.

More precise calculations confirm the approximate reasoning of the foregoing paragraphs. A spherical star cluster with an average star density equivalent to one solar mass per 300 cubic light-years should have enough internal gravitational pull to hold out against the disruptive tidal forces of our rotating galaxy. A somewhat flattened cluster more easily falls prey to the tidal disruption, and it is found that one with a ratio of major to minor axis equal to five requires a density three times greater than does the spherical cluster, to withstand tidal disruption.

It is of interest to apply these results to some of the known clusters. The globular clusters have average star densities well in excess of the above critical densities, and they are well protected against galactic tidal disruption. A cluster like the Pleiades is still on the safe side of the dividing line; the majority of the clusters that we admire in our telescopes are in that respect like the Pleiades. But there are some loose clusters, such as the Hyades, for which the average star density is close to or below the critical density and that hence should be disappearing. The best-known example of a very thinly populated group of stars certainly in the process of galactic disruption is the Ursa Major cluster, to which belong the bright stars of the Big Dipper except the end stars.

Rate of Disintegration of Loose Clusters

It is relatively simple to compute the rates at which very loosely bound star clusters, or star groups, will in all probability disintegrate. We carry out the computations for the most favorable case, one in which at the start the motions of the group members are so attuned that under the influence of the smoothed force field of our rotating galaxy the stars in the group would retain indefinitely the same average distances apart. But this condition cannot be a permanent one, for the galactic field is subject to fluctuations, caused principally by encounters between group or cluster stars and distant field stars. Something very much milder than a collision or a dramatic close passage is all that is needed to divert a cluster star from its original path.

At this moment the Ursa Major group, with a total mass for the established nucleus of the order of 100 times that of our sun, is spread over a volume of space with a diameter of the order of 150 light-years. Computations show that this cluster should double its radius in about 200 million years, and that in about 500 million years the cluster will be so broken up as to have lost its identity.

I can almost hear some readers say, "Well, that is a comfortably long time." But, believe me, cosmically speaking it is a rapid process. Look at it this way: Our sun completes one revolution around the distant galactic center in Sagittarius in about 200 million years. For simplicity — and to avoid big numbers — we have called this interval the *cosmic year*, since in the cosmos it represents a parallel to the year by which we measure times in the solar system. The Ursa Major cluster will double its radius in one single cosmic year, and in 2½ cosmic years it will have vanished as a group. If we keep in mind that the age of our earth (two to three billion years in terms of solar years) is 10 to 15 of these cosmic years, then we see that, cosmically speaking, the Ursa Major cluster is rapidly disintegrating. This cluster represents in many respects a special case. But there are quite a few clusters of the Hyades variety already known, those with average densities below the critical density for stability. The most probable time required for complete disintegration of the least unstable of these clusters is of the order of only 10 to 15 cosmic years. Marked changes are apparently taking place in our Milky Way system in time intervals comparable in length to the age of our earth.

Equilibrium of a Stable Star Cluster

Let us now turn our attention to clusters that are relatively immune to the tidal effects of the galactic field of force. How do these clusters arrange their internal motions and stellar distributions to achieve approximate equilibrium?

If a cluster of stars is to keep approximately the same overall diameter, the member stars must have some motions of their own. For, otherwise, the mutual gravitational attraction of the member stars would draw all of them gradually toward the center, with a resulting collapse of the whole system. The ve-

locities of the individual stars must not, however, be too great, for then large-scale escape of stars from the cluster would occur, with consequent disintegration of the cluster. Apparently, if a star cluster is to be a fairly permanent affair (and we must assume that this is the case for the majority of known dense clusters), there must exist a rather neat division between the total energy of motion (the *kinetic energy, T,* which is positive) and the total energy of position (the *potential energy, W,* which is negative) of all the cluster stars together. This equilibrium condition is expressed by the so-called *virial theorem,* which in the simplest case has the form:

$$2T + W = 0.$$

This relation applies, we remind you, to a stable cluster not affected by galactic tidal forces and in equilibrium. From it we can deduce a very interesting relation involving the mean of the squares of the random velocities, and the total mass and radius of the cluster. We refer the mathematically inclined reader again to Chandrasekhar's text or to the original literature, but in the simplest case,

$$2T = MV^2,$$

where M is the total mass of the cluster and V^2, the velocity dispersion squared, is the mean value of the squares of the random velocities of the member stars; and

$$W = -3GM^2/5R,$$

where G is Newton's universal constant of gravitation, M is again the total mass, and R is the radius of the cluster. Combining these three equations, we obtain the relation:

$$V^2 = 3GM/5R.$$

This formula is of the greatest importance in the study of dense galactic clusters and globular clusters. It states mathematically the sensible condition that, for a cluster of given total mass to attain a certain radius, the star members must be endowed with definite mean square velocities. In practice we can use this formula in reverse: If we measure the radius of a cluster, and if we have (generally from proper motions) some information regarding the random velocities of the stars in the cluster, then we can obtain from our relation a value for the probable mass of the cluster. In the case of the Pleiades, for instance, for an approximate observed value of the average velocity of 0.6 kilometer per second and a radius of about eight light-years, we find that the total mass of the cluster should be about 400 times that of the sun, a value that agrees well with the total estimated mass of the known member stars. For an average globular cluster, radial-velocity measurements indicate velocity spreads of the order of 15 kilometers per second. For a radius of approximately 50 light-years, the deduced total mass of the average globular cluster appears to be somewhere between 100,000 and 1,000,000 times that of our sun.

(To be continued)

Galactic clusters in Auriga, photographed with a 60-minute exposure with the Jewett Schmidt telescope at Harvard's Massachusetts station. M36 is at the upper left; M38 toward the upper right. NGC 1907, a possible companion of M38, is centered about 3⅝ inches from the left edge.

The Metonian Calendar

WE HAVE been using the Gregorian calendar since October 15, 1582; before then, the Julian or Old Style calendar; and before January 1, 45 B.C., the Metonian calendar, which has months beginning at the new moon, and years beginning with the new moon nearest the winter tropic (time of the solstice).

Almanacs nowadays mention the tropical year and give the corresponding golden number. These are relics of the Metonian years. Now, suppose that Julius Caesar and Pope Gregory XIII had failed to establish their reforms, how would the Metonian years apply to our times? The years would begin as follows:

Golden number	Date of mean new moon
I	January 1, 1938
II	December 22, 1938
III	December 11, 1939
IV	December 29, 1940
V	December 19, 1941
VI	December 8, 1942
VII	December 27, 1943
VIII	December 15, 1944
IX	January 3, 1946
X	December 24, 1946
XI	December 13, 1947
XII	December 31, 1948
XIII	December 20, 1949
XIV	December 10, 1950
XV	December 28, 1951
XVI	December 17, 1952
XVII	January 5, 1954
XVIII	December 25, 1954
XIX	December 14, 1955
I	January 1, 1957
II	December 22, 1957
III	December 11, 1958

The Metonian year could begin as early as December 8th or as late as January 5th. Golden number II begins with the new moon coming on the day of the tropic (winter solstice), and in accordance with the Metonic cycle (19 years = 6,939.6017 days and 235 months = 6,939.6882 days), this will occur every 19 years, as follows:

Year	Mean tropic	Difference
1900	Dec. 22.4044, Sat.	−.2722
1919	Dec. 23.0061, Tue.	−.1857
1938	Dec. 22.6078, Thu.	−.0992
1957	Dec. 22.2095, Sun.	−.0127
1976	Dec. 21.8112, Tue.	+.0738
1995	Dec. 22.4129, Fri.	+.1603

The column of differences is that decimal of a day whereby the time of mean tropic and mean new moon differ, positive if the tropic occurs first. Notice that the mean solar tropical year and the mean lunar month begin at very nearly the same time Sunday, December 22, 1957, which is the pivotal date in this 19-year cycle of near coincidences.

Also, 334 years equal 4,131 lunar months with a difference of only .0376 day. As the table below shows, in this 334-year cycle Sunday, December 22, 1957, is also the pivotal date:

Year	Mean tropic	Difference
1289	Dec. 14.4094, Wed.	+.0694
1623	Dec. 22.3129, Fri.	+.0249
1957	Dec. 22.2095, Sun.	−.0127
2291	Dec. 22.0993, Tue.	−.0435

H. PORTER TREFETHEN

TERMINOLOGY TALKS

J. Hugh Pruett

Earth Rotations in 365¼ Days

In April (page 145), while discussing the rotation of the moon, we found that in each revolution around the earth, the moon must rotate one more time than the number of times it changes its facing toward the earth. In a continuation of the experiment we described in April, using coins to represent the earth and the moon, now let the 50-cent piece represent the sun, and the dime represent the earth. With the same reasoning, we shall find that, in 365 of our common solar days, the earth rotates on its axis 366 times.

Suppose while the earth-dime is making one revolution around the sun, it rotates completely twice. The head on the dime will then make one complete change of facing toward the sun. If it rotates three times, it will change its sun-facing twice; four rotations, three changes of facing, and so forth. We see that the earth changes its facing toward the sun one time less than the number of rotations during a revolution. Thus, it takes 366 rotations of the earth for 365 solar days, 365 changes of facing the sun.

This can be calculated approximately also from the fact that any star rises almost four minutes earlier each successive day. This amounts to about two hours in a month, and to 24 hours in a year. There are, then, very close to 366 sidereal days in 365 solar days.

SURELY the first creatures with eyes and reasoning minds ever to turn their eyes heavenward soon became aware of the more conspicuous stars and their interesting arrangements. Certain scholars, using rather abstruse methods of fact finding, believe they can show that as early as 4000 B. C. some of the recognized groupings of today had been mapped out by the primitive peoples.

Constellation, Asterism

Constellation comes from the Latin *con* (with, or together) and *stella* (star). As used today it refers to a number of "fixed" stars apparently grouped within certain boundaries for easy identification. Sometimes these groupings are quite pronounced and natural, but when only faint stars are concerned, the outlines are often anything but easy.

Asterism comes from the Greek *aster* (star). The term is sometimes used in the same sense as constellation, but as now generally employed it is applied to a prominent grouping inside a constellation. Asterisms often have names of their own. Taurus, the Bull, is the name of a fairly large constellation, but included within its boundaries — and well known to students of the starry skies — are two famous asterisms: the Hyades, the V of faint stars with bright Aldebaran at one of the upper tips of the letter; and the Pleiades, that delicate assemblage of tiny points of light resembling somewhat a very small dipper. These two happen to be star clusters, whose stars are associated physically as well as by chance on our sky. The Sickle in Leo, the Northern Cross, the Great Square of Pegasus, are asterisms. Many others could be named, for, as one writer has said, "Poetry has filled the sky with asterisms."

Some well-known asterisms go under different designations in various parts of the world. The familiar Big Dipper of the Americans is the Chariot to the Chinese and the Plough, or Charles' Wain (wagon), in England. One wonders if the reputed head of the present government of China is sufficiently astronomically inclined to be flattered that Mao is the name applied by his countrymen to the Pleiades.

Ancient Constellations

The very early Egyptians certainly gave names to various star groups, but it is said that we have information on none of these. The Chinese were making constellation outlines as early as 2500 B. C. From ancient Mesopotamia may have come the beginnings of a large number of the groupings we use today, and these too may date back as far as 2500 B. C. In later times the Greeks evidently worked them over considerably into the forms that we know. Many familiar to us are mentioned by the Greek poets Homer and Hesiod, who wrote well toward a thousand years before the Christian era.

It seems reasonable that the many widely separated nations of early times gave names of their own to the naturally grouped constellations. It is well known that very few actually resemble the creatures for which they are named, Orion, Ursa Major, and Scorpius being a few possible exceptions. One writer has said that "the figures are likely often symbolic rather than actually resembling the animals." Nor is it at all evident whether the mythological stories connected with the constellations were devised after the groupings were outlined, or if earlier tales were later applied to the sky figures.

Modern Constellations

About half of our present-day star groupings were given a firm status by the Greek astronomer Hipparchus around 150 B. C. Then Ptolemy, 300 years later, gave finishing touches to the work. It is usually stated that 48 of our constellations date from these times. During the past few hundred years many more have been added, especially among the southern stars and in the outlining of groups consisting wholly of dim stars. To list the designers of all these would in this connection be tedious. We recognize 88 constellations today.

Renaming Attempts

There have been attempts in modern times to rename some or all of the well-known constellations in order to honor certain countries or religions. In 1627, Julius Schiller tried to change the pagan names to noted men and objects connected with the Christian church. He wanted to honor certain popes, bishops, and other dignitaries. Canis Major would have become David; Lyra, the Manger; Aries, St. Peter; and so forth. Almost a thousand years earlier the English monk, the Venerable Bede, had attempted to have the zodiacal constellations named for the apostles of Christ. Some thought the sky "should be delivered from pagans and peopled with Christians."

Perhaps the latest renaming escapade was the one undertaken around 10 years ago by A. P. Herbert, an Oxford University representative in the English Parliament. For example, he would have Aquila and Delphinus combined and called the Music Maker, and name the individual stars in it for Strauss, Bach, Mozart, and other great musicians. Cygnus, the Swan, would become China, with the stars rechristened Confucius, Canton, Chiang Kai Shek, and the like. Draco, the Dragon, would be renamed the Tyrants, and its stars, Hitler, Mussolini, Attila, and other meanies. Since Herbert was a famous jester, his scheme failed to carry much weight. His elaborate star maps were published in the *Illustrated London News* (see also *Sky and Telescope,* April, 1943, page 12).

Constellation Boundaries

Until about 20 years ago, star maps and astronomical globes showed the boundaries of most of the constellations as curving and twisting lines something like those bordering the countries of Europe and Asia. They had been irregular and confusing since antiquity, and their exact outlines were as various as were the makers of the celestial maps. In 1930, the International Astronomical Union adopted the plan of Dr. E. Delporte, which determined definitely all boundaries and made them run north and south or east and west — astronomically speaking. This means they follow circles of right ascension and of declination. They are thus as nearly straight lines as are possible on a sphere.

THE INDEX TO VOLUME IX
of Sky and Telescope is now available. This is a detailed cross-referenced index that includes topic and subject references as well as those by title and author.
This and the indexes to previous volumes cost 35 cents each, in coin or stamps.
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Photography of the Counterglow

By Otto Struve, *Berkeley Astronomical Department, University of California*

PROBABLY every reader of this magazine has, at one time or another, been fascinated by the reflection of a beautiful landscape from one of those large, decorative silvered glass spheres which can still occasionally be seen in old-fashioned, formal flower gardens. Mounted on a pedestal, these spherical mirrors reflect a considerable part of their surroundings, with trees, buildings, and clouds all fitted into a distorted pattern of the real landscape. A visitor equipped with a hand camera could make a photograph of the spherical mirror, and thus record on his film a wide field of view — far wider than the limited angle at which the camera would work when exposed directly. True, the images of objects near the edge would be bent into bizarre shapes, and the entire panorama would be on a very small scale. Yet, by interposing the spherical mirror in front of the camera, our photographer would succeed in greatly enlarging his field of view. He could, in fact, regard the silvered sphere as a part of his optical system and consider the entire outfit as a wide-angle camera.

During the last war our armed services were in need of just such a wide-angle system. Hence, experiments were started with different types of convex mirrors in front of conventional photographic lenses. The results were disappointing. The distortions were prohibitive, and the curvature of the field was so great that ordinary films could not be bent to fit it.

The problem was investigated by two Yerkes Observatory astronomers, Dr. L. G. Henyey (now at the University of California, Berkeley) and Dr. J. L. Greenstein (now at the Mount Wilson and Palomar Observatories, California Institute of Technology). They quickly realized that the principal fault of the *convex* mirror could be eliminated by substituting for it a spherical *concave* mirror. This mirror produces a curved image in its own focal plane, which in turn can be photographed by means of a suitably designed camera lens, of small focal ratio. The normal curvature of the lens is made to offset the curvature of the image formed by the concave mirror — this being the essential novelty of the Henyey-Greenstein design. In the case of the convex mirror this compensation could not be achieved.

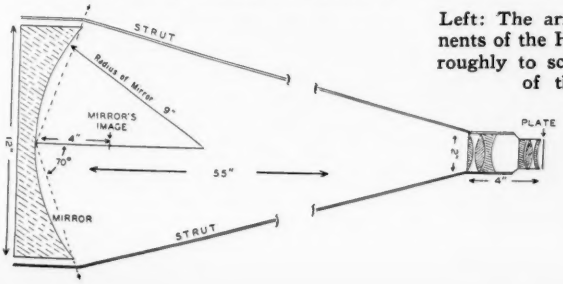
The mirror of the wide-angle camera designed by Henyey and Greenstein here reflects the full extent of the buildings of Yerkes Observatory.

The final design consists of a concave mirror having an aperture of 12 inches and a radius of curvature of nine inches. The camera lens is of a modified Petzval-portrait type and consists of six elements, the largest aperture being about two inches. This f/2 lens is mounted on three thin, inclined metal struts above the center of the concave mirror, and, of course, it faces the latter. The distance from the mirror to the lens is almost 55 inches.

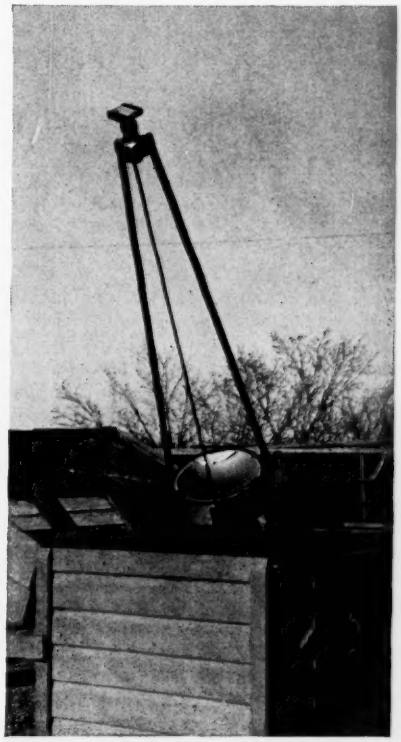
Suppose that the mirror is directed toward the sky to photograph the stars. What is the effective aperture of the device and its focal ratio? Consider light from a single star. It fills the 12-inch mirror as a parallel bundle, with the small lens in front of the mirror and the supporting rods casting their shadows upon the image. Will the effective aperture be 12 inches or two inches? The answer is, neither. The image formed by the mirror is only some four inches in front of the glass surface. The rays converge at a steep angle, and then diverge again. Most of them bypass the Petzval lens altogether, and only about 1/10 (in one plane) are caught. Thus the effective aperture is much less than two inches, in fact, it is only about 0.17 inch.

Similarly, the effective focal length can be shown to be neither the focal length of the mirror nor that of the lens; it is actually 0.34 inch. Therefore, the focal ratio is as before, f/2, and for luminous surfaces the instrument is as fast as any f/2 lens. But the effective aperture of only about 0.2 inch makes it a slow camera for photographing separate stars, for these act as point sources of light.

Of course, it was one thing to conceive this interesting optical system; it was an entirely different task to construct a short-focus photographic objective that would reproduce with critical definition the image of the spherical mirror, and at the same time remove the curvature of the field of this mirror. This part of the work was a problem in optical design. It resulted in the six-component lens, which utilizes four kinds



Left: The arrangement of the components of the Henyey-Greenstein camera, roughly to scale except for the length of the instrument.



Right: The camera in its mounting, showing the manner in which the struts support the camera lens. Yerkes Observatory photograph.

The Milky Way from Cassiopeia to Canis Major, photographed with the Henyey-Greenstein camera, October 12, 1950. The exposure was 15 minutes on Eastman 103a-F emulsion. The zodiacal light appears in the lower left part of the plate. Sirius is at the right, just above the observatory dome. This and the engraving opposite are lent by courtesy of W. W. Morgan, managing editor, "Astrophysical Journal," and the University of Chicago Press.

of optical glass. The large aperture of the spherical mirror was required to give the large field, but the size of this field is limited by the concavity of the mirror, for its raised edges prevent rays that are more than 70 degrees from the optical axis from striking the silvered surface.

Henyey and Greenstein pointed out, in the report of their design to the government, that their camera would cover a field angle of 140 degrees with critical definition, and that it would be useful for photography of the Milky Way, the zodiacal light, the aurora borealis, and the counterglow, at night; and for the study of clouds in the daytime. Besides, they thought that the device could be inverted to serve as a small planetarium-type projector for use in teaching star identification and celestial navigation.

Several test models were constructed in the Yerkes optical shop by Fred Pearson, who made the optical parts, and Charles Ridell, who made the mounting. One of these models has recently been used by Donald Osterbrock and Stewart Sharpless, at Yerkes, to produce spectacular photographs of the Milky Way, the zodiacal light, and the counterglow.

The effective aperture of the instrument is not very different from that of the human eye, and the field and speed (or focal ratio) also somewhat resemble those of the eye. Thus, the photographs are like naked-eye views of the sky. On a direct photograph, with an exposure of 15 minutes on fast blue-sensitive plates (Eastman 103a-O), somewhat fainter stars are shown than the eye alone can see, but the Milky Way produces the illusion of a naked-eye observation.

The photographs show, of course, the shadows of the supporting rods and of the camera at the top. Moreover, the dim outlines of Yerkes Observatory, with its domes and lighted windows, appear along the circular rim of the field. The camera was driven by a clock; hence the terrestrial objects are peculiarly distorted.

A very interesting photograph is that of the counterglow, or Gegenschein, obtained on October 10, 1950, on an Eastman 103a-F red-sensitive emulsion. This picture has been copied to high contrast, and it shows the counterglow very clearly as a diffuse, luminous patch, roughly elongated along the ecliptic, in the lower right-central part of the plate; it is above and to the right of the observatory dome.

The counterglow has been known for almost 100 years. It was actually discovered independently three times: by T. J. C. A. Brorsen in 1855, by T. W. Backhouse in 1868, and by E. E. Barnard in 1883. Undoubtedly, the small contrast of the counterglow and the fairly luminous night sky made it a difficult object in the northern latitudes of most European observatories. Even at the more favorable sites of modern mountain observatories, to see it requires a good deal of experience on the part of the observer. But in late September and in October, when the counterglow falls in the uniformly faint regions of Pisces and Cetus, most persons can distinguish it under favorable conditions without too much trouble.

It is not known exactly when the first successful Gegenschein photographs were obtained. A. E. Douglass, of the University of Arizona, announced long ago that he had recorded it with a specially constructed camera; and Miss Margaret Harwood, in 1924, used a short-focus lens attached to a 10-inch guiding telescope on Mt. Wilson. Soon after the first World War, the Gegenschein was photographed at Yerkes with a war-surplus "gunsight" lens of short focal ratio.

A more conspicuous observational effort was made by C. T. Elvey in 1932. With the help of a photoelectric photometer, he measured the brightness of the counterglow and derived for several nights a series of isophotes showing its intensity distribution against the sky. He commented upon "the changing form and position" of the counterglow.

As a rule, the counterglow is visible as a hazy spot of light centered exactly in opposition to the sun. In a schematic diagram, C. Hoffmeister placed it 180 degrees from the sun on the ecliptic; he regards the Gegenschein as a condensation of the faintly luminous zodiacal band that itself is an extension of the zodiacal light, joining the upper tips of the morning and evening zodiacal cones.

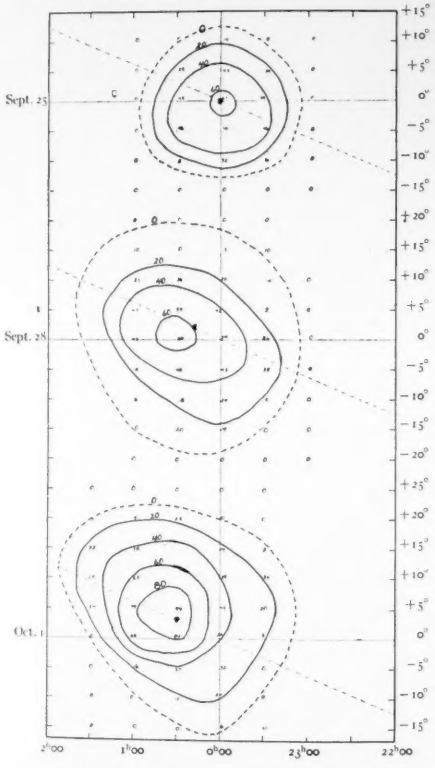
Some very fine photographs of the counterglow were obtained at Windhuk in South Africa during a German expedition in 1935. These photographs were reproduced in the 1948 edition of Newcomb-Engelmann's *Populäre Astronomie,* but it is believed that the original plates were destroyed during the last war.

It has been thought for a long time that the counterglow consists of small meteoric particles which, according to H. Gyldén and F. R. Moulton, have a tendency to linger at points in their orbits that lie along the line joining the sun and earth. These particles remain for some time in the vicinity of opposi-

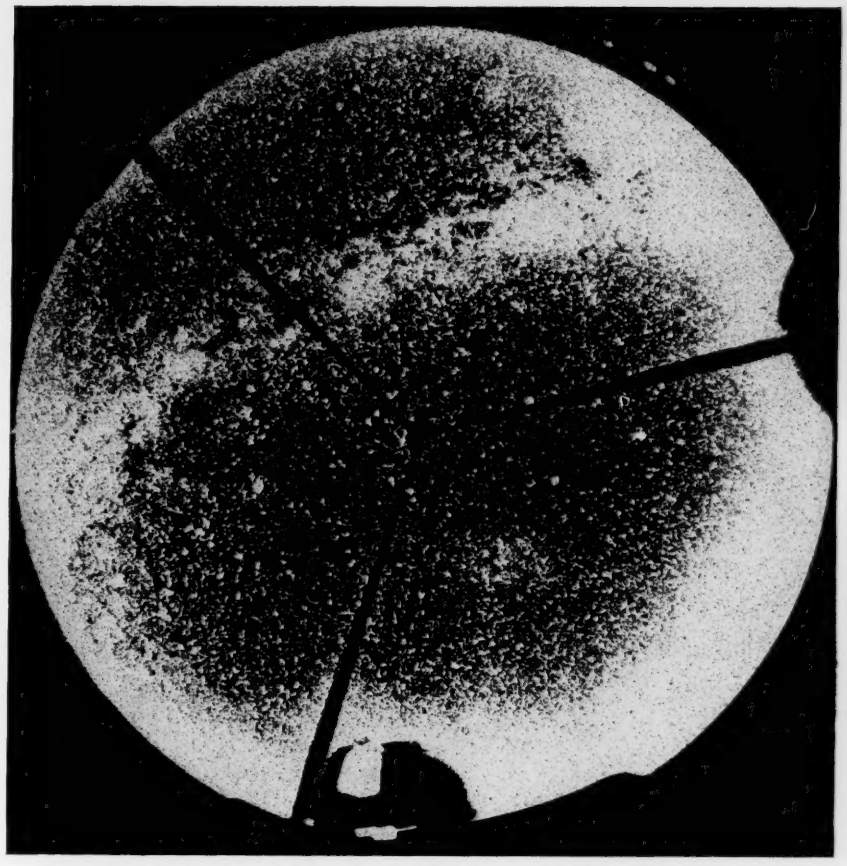
tion, and then gradually disappear within the diffuse interplanetary medium that constitutes the zodiacal light.

This hypothesis was strengthened by the negative results of previous observers who attempted to find a diurnal parallax of the counterglow. For the moon, this diurnal change of apparent direction amounts to two degrees, because at moonset an observer is removed nearly 8,000 miles from his position at moonrise, and the moon is 240,000 miles away. Thus, were the counterglow sufficiently near the earth, its apparent direction relative to the star background would shift from the time of its rising to that of its setting for any one observer. But some observers even reported a negative parallax for simultaneous observations made from different parts of the earth. These results were, however, attributed to the effect of absorption in our own atmosphere, which makes it very difficult to ascertain exactly the true location of the center of the counterglow.

It was, therefore, something of a surprise when several Russian astrophysicists announced in the past two or three years that there was some evidence that



Isophotes of the Gegenschein plotted by C. T. Elvey from observations with a photoelectric photometer attached to the 40-inch Yerkes refractor. The point opposite the sun is a small black dot; the ecliptic, a dashed line. The outermost zero isophote is rather uncertain. The changing form and position of the Gegenschein are evident. Illustration from the "Astrophysical Journal," January, 1933.



The Gegenschein appears above and to the right of the observatory dome as a horizontally elongated patch. Farther above and to its right is the Great Square of Pegasus. The plate has been copied to high contrast from a 15-minute exposure on Eastman 103a-F emulsion, October 10, 1950. This and the picture opposite were taken by Donald Osterbrock and Stewart Sharpless, at Yerkes.

suggested a terrestrial origin of the Gegenschein. For example, D. A. Rojkovsky found from photographs made at different times throughout the night that there is a pronounced periodic daily motion of the center of the counterglow which suggests a diurnal parallax of 3.5 degrees of arc, corresponding to a distance only about half that of the moon. As a rule, the eastern halves of the isophotes are well defined, but the western halves are more and more uncertain after midnight, and the whole phenomenon takes on the appearance of a cone of light with the counterglow at the top and the base near the western horizon. The Russian astronomers call this cone a "false zodiacal light," because it appears in that part of the sky where the ordinary zodiacal light is not supposed to be visible.

In another paper printed in the *Astronomical Journal* of the Soviet Union, V. G. Fessenkoff concludes that the counterglow is a gaseous tail which accompanies the earth and is directed away from the sun, with a slight curvature resulting from the action of Kepler's second law. This is essentially the same kind of phenomenon as that which gives rise to the tails of comets. Fessenkoff computes that the density of the earth's gaseous tail decreases by a factor of two at intervals of between four and five times the radius of the earth.

Although some observations appear to be favorable to this revolutionary theory, other work makes one pause and wonder. For example, M. G. Karimov found that the spectrum of the counterglow is identical with that of the earth's upper atmosphere, showing the usual emission lines and bands that are well known in the light of the air glow. It would be strange if a tenuous tail should really display a spectrum so nearly identical with that produced in the much more compressed layers of air where the normal lines of the night sky originate.

Another complication arises from the theoretical work of N. B. Divari, also published in the Russian *Astronomical Journal*, in which he has computed the pressure of the solar radiation upon atoms of various gases known to exist in our atmosphere. To account for a gaseous tail, the radiation pressure of sunlight at our distance from the sun would have to be greater than the gravitational acceleration produced by the earth upon atoms a few hundred miles

above the earth's surface. Even in the case of the hydrogen-alpha line, the earth's gravitation under these conditions greatly surpasses the radiation pressure from the sun, and Divari concludes that no tail would be formed in this manner. He admits that his computations do not exhaust the question, because it is known that in comets the pressure of radiation is sometimes much larger than ordinary computations would lead us to suppose. Hence, it is still possible that there are unknown factors that result in a force away from the sun, which conceivably might exceed the earth's own attraction for small particles. But as yet there is no definite reason to believe that such a force really exists.

The photograph of the Gegenschein with the Henyey-Greenstein wide-angle camera reproduced here was first published in the *Astrophysical Journal,* January, 1951. The photographers, Osterbrock and Sharpless, point out that the position of the center of the Gegenschein agrees closely with the longitude of the antisolar point, an observation which is at variance with the recent determination of Rojkovsky. Thus, this photograph is unfavorable to the hypothesis of a gaseous tail. Other investigations are known to be in progress, and we should know in the near future whether or not there is any real basis to the claim that the counterglow possesses a large parallax.

SOLAR X-RAYS

Photon counter tubes sensitive to four narrow bands of the X-ray and ultraviolet spectra (0-10, 1150-1350, 1425-1700, and 1750-2150 angstroms) were carried to a height of 150 kilometers by the V-2 rocket fired at White Sands Proving Ground on September 29, 1949. The results obtained were reported at the winter meeting of the Optical Society of America by H. Friedman, S. W. Lichtman, and E. T. Byram, of the Naval Research Laboratory.

X-ray emission was first recorded at 85 kilometers above sea level, indicating a short wave-length cutoff of the solar emission at about 7 angstroms. The almost total absorption of this radiation occurred in a relatively narrow range of altitude, agreeing with the height of the E layer and with the theory that the E layer is produced largely by X-rays emitted from the sun's corona. Maximum absorption occurred at about 65 kilometers for 1150-1350, and at 100 kilometers for 1425-1700 angstroms. Light in the fourth band was first detected at seven kilometers, but at heights above 15 kilometers the records were saturated. The authors find these experimental results in general agreement with the theory of the distribution of molecular and atomic oxygen and of ozone.

NEWS NOTES

By Dorrit Hoffleit

ECHOES FROM THE MOON

In the March *Proceedings* of the Institute of Radio Engineers, F. J. Kerr and C. A. Shain, of Australia, report on experiments made with 20-megacycle radio echoes from the moon, mainly for the purpose of studying low-angle transmission through the ionosphere. During its free time, they used a broadcast transmitter with a fixed aerial system. They obtained echoes during 24 of 30 experiments in one year.

They noted two types of signal fading, a slow and a fast. The first was consistent with an ionospheric origin, while the fast fading (on the order of seconds) could be traced to the librations of the moon, which introduce a Doppler broadening in the reflected frequencies. From this effect, the scientists conclude that the moon is a "rough" reflector at the frequency they used, and presumably at all higher frequencies.

A HIGHLY COMPACT SYSTEM

Studying faint galaxy plates taken with Harvard's Jewett Schmidt telescope, Dr. Carl Seyfert, of Barnard Observatory at Vanderbilt University, discovered a very compact group of galaxies in Serpens. There appear to be six members, including NGC 6027, ranging in apparent magnitude from 14.7 to 16.9 (photographic), and all situated within a region only two minutes of arc in diameter. From the velocity-distance relation found by Hubble years ago, the velocity for two of the members of this group determined by Humason at Mount Wilson implies a distance of 26,600,000 light-years. This in turn indicates that this cluster of faint galaxies (described in the *Publications* of the Astronomical Society of the Pacific) is some 30 to 130 times more compact than the most closely packed groups hitherto known, Stephan's quintet and a quartet in Leo near NGC 3193.

ARCTIC RADIO ASTRONOMY

Within the Arctic Circle, at latitude 69° or 70° north, Dr. Jaakko Tuominen, of the Helsinki Observatory in Finland, plans to set up a new laboratory for radio astronomy, operating on a wave length of two meters. The chief advantage of the location will be to record solar radiation almost continuously throughout the summer. The same equipment could also be used for recording galactic radio noise.

RALPH E. WILSON RETIRES

On May 1st, Dr. Ralph E. Wilson retired from the staff of the Mount Wilson and Palomar Observatories. He was honored on June 20th by a symposium on "Radial Velocity Programs of Pacific Coast Observatories," at the summer meeting of the Astronomical Society of the Pacific, of which he was president in 1946. Dr. Wilson came to Mount Wilson in 1938, prior to which he spent two decades in the department of meridian astronomy of the Carnegie Institution. His previous work was at Lick Observatory and Goodsell Observatory.

Dr. Wilson has spent most of his career in research on the motions of the stars. He took a leading part in preparing the *General Catalogue* of proper motions of the Dudley Observatory at Albany, N. Y., and he recently completed a compilation of all known stellar radial velocities.

HAYDEN PLANETARIUM TECHNICIAN DIES

Frederick Raiser, supervising technician of the Hayden Planetarium in New York City, died suddenly of a heart attack on May 11, 1951, at the age of 43. He was a self-taught practical engineer, and was responsible for many innovations in the techniques of projecting still and motion-picture panoramas of the sky and earth under the highly specialized conditions of a planetarium demonstration. He joined the staff of the planetarium only a few weeks after it opened to the public in October, 1935.

IN THE CURRENT JOURNALS

THE CANADIAN METEOR CRATER, by V. B. Meen, **Scientific American,** May, 1951. "An account of the discovery and exploration of the two-mile crater on the barrens near Hudson Bay. If it is conclusively shown to be meteoritic, it is the largest yet found on earth."

KOURGANOFF'S CONTRIBUTIONS TO THE HISTORY OF THE DISCOVERY OF PLUTO, by Gibson Reaves, **Publications,** Astronomical Society of the Pacific, April, 1951. "The thesis of 'pure chance' in regard to the discovery of Pluto is absolutely untenable. Pluto was 'discovered' in 1915 by Lowell and 'rediscovered' in 1919 by Pickering by the methods of celestial mechanics, before its 'physical' discovery by Tombaugh at the Lowell Observatory."

THE ELECTRICAL PHOTOMETRY OF STARS AND NEBULAE, by Joel Stebbins, the George Darwin lecture, **Monthly Notices,** Royal Astronomical Society, **Vol. 110,** No. 5, 1950. "In any event it now seems truer than ever that in astronomy as elsewhere the applications of the photoelectric cell are limited only by the imagination of the experimenter."

SUPER - SCHMIDT

THE SUPER-SCHMIDT meteor camera sketched on the back cover of *Sky and Telescope* in February, 1949, has now become reality. The Perkin-Elmer Corporation has completed the first of six instruments, and it was flown to New Mexico late in May for installation at the Soledad observing station of Harvard Observatory, near Las Cruces. The completed instrument is pictured on the front cover of this issue, as it appeared during final testing on the stars at Norwalk, Conn.

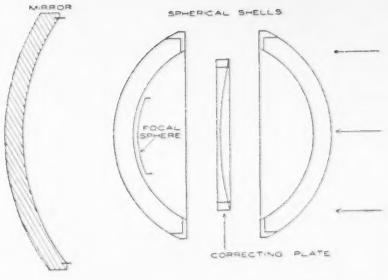
Whereas cameras hitherto in use for meteor photography have been able to catch meteors only of about zero magnitude and brighter, the new instrument, with an effective focal ratio of 0.85, should reach at least 4th magnitude (visual). Thus, it should make possible photography of meteors the size of buckshot; earlier cameras could only record meteors down to the size of marbles. Even on a perfectly dark night, the limiting exposure is expected to be about six minutes. The 52-degree field covered by the camera takes in about 1/10 of the area of the visible sky, or 10,000 times the area of the moon. The rate of catching meteors is expected to be 40 times that of the meteor cameras now in use.

The design of the super-Schmidt, based on an optical system by Dr. James G. Baker, research associate at Harvard Observatory and chief optical consultant at Perkin-Elmer, is described by Dr. Fred L. Whipple in the article, "The Harvard Photographic Meteor Program," in the issue of *Sky and Telescope* referred to above. Dr. Whipple is in charge of the Harvard meteor program, which is supported by the Navy Bureau of Ordnance.

The finished instrument weighs 5,000 pounds, including the electric clock drive, the large yoke mounting, and the telescope assembly. This consists of a spherical lens, 18 inches in diameter, at the head of the instrument, a double achromatic correcting plate behind it, another 18-inch spherical lens, and a concave, 23-inch mirror. A curved filmholder and rotating shutter are placed in the center of the camera in front of the inner lens. The axis of the shutter comes up directly through the mirror.

Right: The massive camera is opened into two sections to make possible changing the film. Photograph by George Bakes.

Below: The super-Schmidt camera principle requires two spherical lens shells that are concentric with the mirror. The central correcting plate is hyperchromatic.



The position of the filmholder and shutter makes the camera unlike any other, because the optical system must be taken apart each time the camera is loaded. After loading, the optics are automatically reset to within tens of thousandths of an inch of their former position. Light rays coming in from the heavens are bent as they pass through the outer lens, the correcting plate, and the inner lens. The corrected rays are reflected by the mirror and pass through the inner lens once again before coming to a focus on the surface of the film. The effective aperture is 12 inches.

A single sheet of film, 7½ inches in diameter, must be heated and pressed by air into a deep spherical shape to fit on the filmholder, which has an 8-inch radius of curvature. A vacuum system keeps the film against the holder. The rotating shutter turns at 1,800 revolutions per minute; hence any meteor recorded during an exposure is photographed as a successive series of dashes, enabling measurement of its deceleration in the atmosphere.

A second meteor camera will be delivered to Harvard for its Dona Ana station at Las Cruces within the next few months. This will permit simultaneous photography of meteors from the two stations, 18 miles apart, for height determinations. Two similar cameras are being built for Canada's Dominion Observatory in Ottawa (to be operated from a new site in western Canada), and two more will be for the Air Force Geophysical Research Directorate in Cambridge, Mass. The Air Force cameras will be operated initially by Harvard.

Grinding one of the 18-inch spherical lens components, which are essential elements in the wide-angle high-speed meteor camera. Photo by George Bakes.

Amateur Astronomers

Plans for the Chapel Hill Convention Exhibit

THE ASTRONOMICAL LEAGUE hopes to see the largest display of amateur astronomers' props in its history at the eclipse convention September 1-3, according to G. R. Wright, the convention chairman. Everything an amateur uses or has thought up as far as the drawing stage is earnestly requested by the exhibit committee to make this display one to talk about back home.

There are no restrictions on the nature of the exhibits, except that they be of astronomical interest, but emphasis will be on observing equipment used for solar work, in keeping with the convention theme. The committee suggests various items, among which are solar filters (complete or in part), solar eyepieces and accessories, polaroid devices, solar photographs and sketches. Also desirable for exhibition are telescope mountings and their accessories, parts, patterns and castings, useful equipment with pocketbook appeal, war-surplus assemblies, photoelectric photometers in any stage of completion, clock drives, finder telescopes, pictures and models of observatories, homemade planetariums, training and demonstration models.

In addition, societies are urged to exhibit bulletins, pictures or scrapbooks, observing records. This year, commercial displays of astronomical articles of any kind are invited. No sales will be allowed on the premises of the University of North Carolina, but exhibitors may take orders for future delivery and payment.

The exhibit hall will be at the Morehead Planetarium, in the same room with the registration desk and bulletin board. Electrical outlets will be available for operating equipment. An outside door connects directly with the parking area, and T. W. Stone and his committee from Richmond will check in the exhibits as they arrive. All exhibit space will be free, and there will be no competition among exhibits.

Advance notice required. As the exhibit is being planned by a committee from Richmond, everything possible must be done in advance. Everyone entering an exhibit should write to T. W. Stone, 3220 Hanes Ave., Richmond, Va., giving: 1. Name and address. 2. Society affiliation, if any. 3. Name and description of entry. 4. Purpose for which it is used. 5. Overall dimensions of article or collection. 6. Arrangements required, whether vertical or horizontal, floor, table, or wall space. 7. Instructions for returning the shipment, if you cannot attend the convention.

Do not ship anything to Richmond. Send or take your exhibit to Chapel Hill, and notify Mr. Stone as above in either case. Shipments should be addressed to Dr. Douglas Duke, Astronomical League Convention, Morehead Planetarium, Chapel Hill, N. C. Be sure the shipment carries your name and return address, and allow ample time for it to reach Chapel Hill before Friday, August 31st. Packing or crating should be such that it can be re-used for return. Exhibits will be returned collect. For first-class parcels, include return postage at the time they are submitted.

Convention registration. Up to May 20th, 43 reservations for the convention had already been received. For reservations, send $5.00 per person to Miss Elizabeth Fazekas, convention treasurer, 3309 Scott St., Portsmouth, Va. Of this, $1.00 is for registration; the remainder will be applied on dormitory fees with the exception of 50 cents per month late reservations charge after July 1st. Further details on the 1951 Astronomical League convention appeared in *Sky and Telescope,* April issue, page 142, and May, page 168.

Astronomy in Jerusalem

OUR NEWLY FOUNDED Amateur Astronomers Association of Jerusalem is planning to erect a small observatory in Jerusalem that will help in our teaching work with adults and youth, and we are also interested in a public planetarium. We have been promised a suitable place for the observatory, and we hope to obtain the necessary sum for the building. Conditions here seem favorable for celestial observations, as indicated by data I have collected.

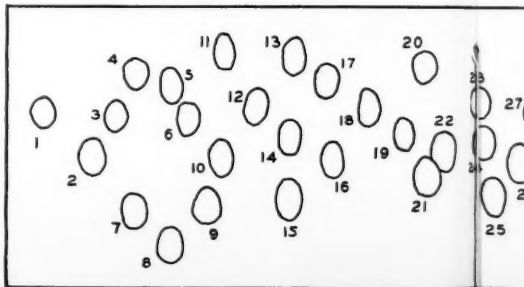
In the town itself and in the vicinity are numerous hills ("Jerusalem, mountains around it." *Psalms* 125.2) and the town itself is a quiet place without heavy industry and without smoke. It is located more than 800 meters above sea level, in latitude 31° 47′ north, longitude 35° 13′ east. The geological conditions seem to be less favorable — almost all the land is composed of marine sediments, and there are no primary rocks.

Daytime cloudiness for the past 15 years is not unfavorable, for the per cent of possible sunshine ranges from a low of 45.5 in January to 97.7 in July, with six months of the year averaging 78.2 or higher. Whole days of cloudiness

American Association of Variable Star Observers Meets At

AT THE AAVSO meeting on May 11-13, in addition to papers and business sessions, successful observing was enjoyed at the Georgetown University Observatory on Friday evening, and at the U. S. Naval Observatory the following night, in conjunction with inspection of the two institutions.

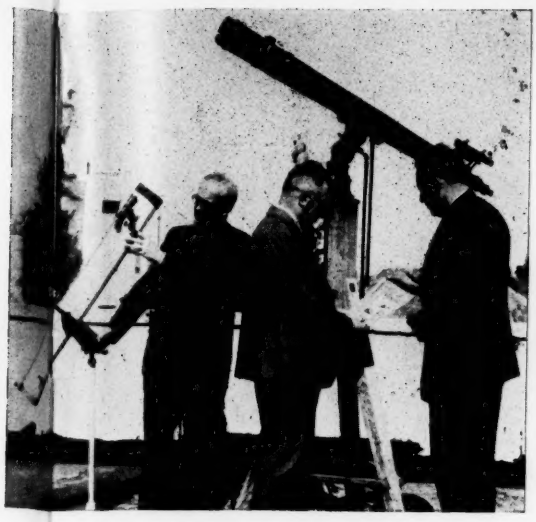
Light curves of unusual variable stars were displayed during the meeting by Mrs. Margaret Mayall, recorder of the AAVSO. Among these were R Scuti and R Coronae Borealis, each covering more than 100 years of observations. These had been compiled and plotted by the late recorder, Leon Campbell. Although his death on the day preceding the opening of the meeting was a sad event, the program was carried out as arranged, in tribute to his work.



KEY TO PHOTOGRAPH

1, Mrs. A. Hamilton. *2*, M. Cilley. *3*, R. M. Hamilton. *4*, Dr. J. Q. Gant. *5*, E. Oravec. *6*, L. Hiett. *7*, N. Mansker. *8*, W. Bissette. *9*, J. Perkins. *10*, G. R. Wright. *11*, D. Strayhorn. *12*, K. Weitzenhoffer. *13*, H. J. Walls. *14*, J. Lankford. *15*, T. Cressy. *16*, Mrs. LuCaric. *17*, J. Streeter. *18*, G. Scholz. *19*, M. Sterns. *20*, J. Edmonds. *21*, N. J. Heines. *22*, R. T. LuCaric. *23*, C. Fereday. *24*, Mrs. LeRoy. *25*, Mrs. M. Mayall. *26*, M. Stahr. *27*, D. Nicklas. *28*, T. Jenkins. *29*, C. H. LeRoy. *30*, C. Werntz. *31*, J. V. Lincoln. *32*, M. McCarthy, S.J. *33*, J. S. Hall. *34*, R. Rhynsburger. *35*, F. J. Heyden, S.J. *36*, W. Dworzan. *37*, J. Weinstein. *38*, Mrs. Ford. *39*, C. Johnson. *40*, C. B. Ford. *41*, I. Warthen.

Members and guests of the AAVSO gathered at meeting, May 11-1



The founders of the AAA of Jerusalem are E. Heilbronner (standing at his 4-inch Newtonian reflector), J. Smoira (center), and D. V. Zaitschek.

do not occur at all in the period June through September, but these facts must be accepted with reserve, for from my own experience I know that the nights of July, August, and September are partly cloudy, especially in the late hours — in the morning the clouds disappear and the day is clear.

Our climate is on the whole dry — Jerusalem especially has low relative humidity, the yearly mean being 60.3 per cent. The monthly mean fluctuates from 45 per cent in May to 72 per cent in January. For the night hours alone the yearly mean is 69.4 per cent, May being lowest with 53 per cent, and September and August highest, 78 and 77 per cent, respectively (the cloudy nights that I mentioned above).

Less favorable are the relatively great fluctuations of temperature between day and night, and especially the abrupt cooling after sunset. The yearly mean of fluctuations between day and night is 9.4° C., reaching 12.2° (22° F.) in August.

There is as yet no chair in astronomy at the Hebrew University, and all the members of our circle are amateur astronomers only. We are scientists, physicians, teachers, university and college students, and our number is small. The instruments at our disposal are also few and small; they include a 4¼-inch refractor and a 4-inch reflector. The university has also one 6-inch Cassegrainian reflector with a clock, received as a gift from the United States shortly before the war. It is at present on the university campus on Mt. Scopus, from which we have been cut off for over three years. There is one more 4-inch refractor in Jerusalem; another such instrument is in Tel-Aviv, as well as a clock-driven 8-inch reflector, made by an amateur.

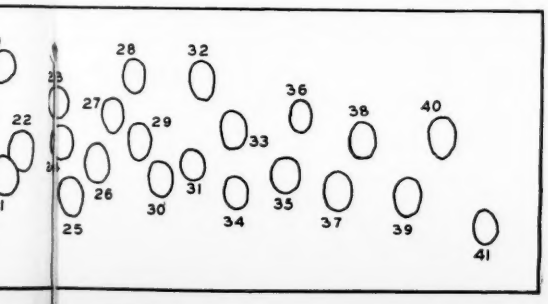
Our activity in popular instruction is rather wide. We hold lectures on astronomical subjects, courses for adults and youths, especially for pupils and their teachers. The lectures are supplemented by observation evenings at the telescopes. Lectures are given in other towns and agricultural settlements as well. We publish monthly notes on the sky in the daily press, articles in popular scientific publications and in youth periodicals, and we broadcast lectures over the local radio network.

Of course, we follow modern astronomical literature, but in Hebrew it is very poor. Not always have the right books been chosen for translation, and there is no comprehensive astronomical textbook in Hebrew. The only booklet which is not a translation was written by one of our members, the late M. Ben-David.

For the observatory, we plan to erect one of the 4-inch telescopes and to build a 6-inch reflector, the pyrex disk being already in hand. We would be interested in hearing from amateur and professional astronomers and groups in the United States.

D. V. Zaitschek
Hebrew University
Jerusalem, Israel

Meets at Washington, D. C.



gathered at Georgetown University for their spring
ng, May 11-13, 1951.

North Central Regional Convention Held in Chicago

A SPECIAL demonstration of the Zeiss projector climaxed activities for over 50 amateurs meeting at Chicago's Adler Planetarium for the North Central regional convention of the Astronomical League, on May 11th and 12th. Dr. Albert V. Shatzel explained the instrument in detail, and then demonstrated such phenomena as the regression of the moon's nodes, precession of the earth's axis, the sky at the equator and the south pole, and a seven-second year.

Dr. Thornton Page, Yerkes Observatory, was the featured speaker at the banquet Saturday night, giving an illustrated lecture, "Beyond the Milky Way." Dr. Page discussed our present yardsticks of space, and indicated current problems of extragalactic research. Dr. C. M. Huffer, Washburn Observatory, then briefly outlined some of the outstanding astronomical developments of the past year.

A wide variety of astronomical topics was covered during the regular Saturday sessions at the Adler Planetarium, headquarters of the host group, the Burnham Astronomical Society. Asteroid observations by amateurs were encouraged as Dr. Shatzel presented his work in determining rotational periods by photometric observations of magnitudes, and as Herbert Cornell, of the Milwaukee Astronomical Society, discussed an asteroid ephemeris prepared by him for that group.

E. A. Halbach, of Milwaukee, a former president of the Astronomical League, was elected regional chairman, successor to Ralph N. Buckstaff, of Oshkosh. Re-elected were H. B. Porterfield, of Madison, vice-chairman, and Elizabeth Wight, of Milwaukee, secretary-treasurer.

Owen Gingerich
Goshen, Ind.

THIS MONTH'S MEETINGS

Chicago, Ill.: The 11th annual observation party of the Burnham Astronomical Society will be held at the home of Mr. and Mrs. H. C. Torreyson, Mt. Prospect, Ill., on Saturday, July 14th.

Columbus, Ohio: At the July 13th meeting of the Columbus Astronomical Society, 8 p.m. at McMillin Observatory, Leon N. Zechiel will speak on "Invisible Double Stars."

Dallas, Tex.: The Texas Astronomical Society will hold its second field meet of the year on July 23rd, at 1446 Glen St., on the lawn of W. L. Oliver, who expects to have his 16-inch reflector in operation for the meeting.

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BOOKS AND THE SKY

THE PRIMEVAL ATOM

Georges Lemaitre. D. Van Nostrand Co., New York, 1950. 186 pages. $3.00.

THE theory of relativity and the observation of the red shift of light from distant galaxies were soon linked together in the development of various theoretical cosmologies. Canon Lemaitre has taken an active part in the development and application of cosmological speculation, and this book presents a personal, historical outline of his work in this field. It consists essentially of five resumé articles or addresses here translated and assembled without major revision. The original publications date from 1929 to 1945; each is essentially a complete statement in itself, and there is consequently much repetition. An appendix contains most of the mathematical derivations of formulae used in the text. The articles were originally planned to be semipopular in nature, are written for an educated but non-technical audience, and are of interest without detailed mathematical reasoning. The translation, by Serge and Betty Korff, does not impress this reviewer as too successful; sentences and phrases often remain in stilted and transliterated French. Meanings are clear, however, and the Gallic logic and lively style of the author have a real charm.

In several of the essays and in the appendix an outline of non-Euclidean geometry is given, together with the relation between matter and spatial curvature. Closed (elliptical) spaces are discussed in detail, and a wealth of vivid images is used to make plausible the ideas of a curved space, of finite volume without boundary. Then the question of rate of variation of the radius of curvature of space is introduced. The details of the balance between the repulsive force (represented by the cosmological constant) and the gravitational attraction are worked through, and Lemaitre discusses extensively possible details of the expansion. If we imagine the direction of the flow of time to be temporarily reversed, to picture the "beginning," we would find that most relativistic cosmologies lead to a dense small universe not more than three billion years old. If this primeval nebular universe is initially gaseous and in equilibrium, gravitational instability and contraction of denser regions leads to expansion. Denser regions now still exist as clusters of galaxies (or the larger density fluctuations recently found in the Lick Observatory survey). Once initiated, the expansion continues, probably indefinitely.

To this essentially classical relativistic picture, Lemaitre adds two major speculations of his own. The early high-density stage has recently been dismissed extensively by those interested in the origin of the elements (Gamow, Teller, Alpher and Herman, van Albada, and others). Lemaitre, writing considerably before these developments of contemporary nuclear physics, imagines that all the atoms in the universe were once concentrated in one gigantic, naturally radioactive, unstable atom. If all the mass of the universe were packed to a density such that the protons were in contact, they would occupy a space only one astronomical unit in radius —but at a density of a billion tons per cubic centimeter! The decay, with emission of energetic photons and nucleons, through successively smaller lumps, ended in the natural stable elements we now know, plus an expanding cloud of highly energetic decay products which Lemaitre identifies with the cosmic rays. As he puts it:

"The evolution of the world can be compared to a display of fireworks that has just ended; some few red wisps, ashes and smoke. Standing on a well-chilled cinder, we see the slow fading of the suns, and we try to recall the vanished brilliance of the origin of the worlds."

"The sun-atom splinters into fragments . . .hurling into the vacuum particles which are fast enough to escape the attraction of the entirety. . . . Rays travel in a straight line in the still-increasing desert of space, until they encounter a lost oasis, our galaxy, a chilled seed, our Earth, and discharge an electrometer, proving the formation of suns."

More recent physical theory has favored a building up of the light elements from an original dense neutron gas, that is, evolution of the elements from simple to complex. Nevertheless, the decay of polyneutrons has been suggested as the origin of the heavier elements. Thus, while Lemaitre's suggestions stand somewhat outside the current trend in physics, they were 15 years ahead in the progress in

NEW BOOKS RECEIVED

FROM THE LIFE OF A RESEARCHER, *William Weber Coblentz*, 1951, *Philosophical Library*. 238 pages. $4.75.

Autobiographical reminiscences by W. W. Coblentz, long associated with the National Bureau of Standards, give an insight into the thoughts of a research scientist. The astronomical references are many.

A NEW THEORY OF GRAVITATION, *Jakob Mandelker*, 1951, *Philosophical Library*. 25 pages. $2.75.

A mathematical treatment, described on the jacket as presenting "a new theory of gravitation which harmonizes with the polar nature of electrostatic and electromagnetic fields.... The author's approach to this perennial problem is both simple and direct and is based on the premise that radiation is a manifestation of force directly opposed to gravitation."

MONTHLY STAR MAPS, *C. H. Cleminshaw*, 1951, *Griffith Observatory*, P. O. Box 9787, Los Angeles 27, Calif. 32 pages. 65 cents.

A booklet by the associate director of the Griffith Observatory includes "A Start on the Stars," monthly white-on-black star maps, and tables on constellations, the 150 brightest stars, index of stars by constellations, special names of stars. Planet positions and configurations through 1960 are described.

THE HEAVENS ABOVE, *J. B. Sidgwick*, 1950, *Oxford University Press*. 333 pages. $4.00.

This first American edition of a 1948 volume has been prepared by Warren K. Green, of Amherst College Observatory. Subtitled A Rationale of Astronomy, the book presents a novel approach "to a clear understanding of the fundamental problems of both classical and modern astronomy," as Dr. Green notes in his preface.

this still speculative field. Similarly, the picture of cosmic rays as primeval decay products is somewhat at variance with recent suggestions. Cosmic rays may be relatively young, and carry a much smaller fraction of the total energy of the universe than was first assumed.

Lemaitre discusses older cosmogonic hypotheses, as well as his relativistic model. He does not consider kinematic relativity or the work of Hoyle, Bondi, and Milne. He briefly outlines subsidiary processes occurring at a later stage in the expansion, such as the formation of elliptical nebulae by collision of gas clouds; the formation of planetary systems, and the initiation of stellar energy generation.

Altogether, this is a fascinating book, presenting a broad, if personal, view of the mystery of the "beginning."

JESSE L. GREENSTEIN
Mount Wilson and Palomar Observatories

THE GROWTH OF PHYSICAL SCIENCE

Sir James Jeans. Cambridge University Press, New York. Second edition, 1951. 364 pages. $3.75.

THE death of Sir James Jeans in 1946 deprived the astronomical world of one of its best-known writers. **The Universe Around Us, The Mysterious Universe,** and **The Stars in Their Courses** have been read by almost everyone interested in astronomy.

The first edition of **The Growth of Physical Science** was published after the death of the author. The present volume is the second edition and has been corrected for errors and edited for publication by P. J. Grant, of the Cavendish Laboratory, but we are informed on the jacket that "in plan and style the book remains as Jeans wrote it."

The illustration on the cover jacket is a composite of the painting of The Alchemist and a photograph of the dome of the 100-inch telescope. This aptly shows Jeans' plan to sketch the growth of science from the very beginning to the latest development. He parallels the advance of astronomy with that of other sciences, particularly mathematics and physics, with short notes on the development of medicine. The first chapters are easy to read and present little-known items of interest about well-known scientists of the past. It is our belief that many readers will find some parts of the later chapters difficult to read, and we predict that most will skip the details, such as, for example, the pages about Cardan and the solution of the cubic equation. Jeans passes the subject off in a seven-line footnote which begins, "The solution of the cubic is a simple matter to have caused such a commotion."

The sections on astronomy trace the development of ideas from the "Remote Beginnings" to the "Era of Modern Physics." The personalities of the great astronomers are vividly portrayed by the pen of the author, and the reader has the advantage of having recalled for him in each chapter the development of mathematics and physics during the same centuries.

In Chapter V, "The Birth of Modern Science," Jeans compares (among others) the life and works of Copernicus and Tycho Brahe. It is gratifying to read in one paragraph a statement, the content of which has been growing in the mind of the reviewer for several years, as follows: "The latter [Copernicus] had been a great mathematician and a great theorist, but was weak as an observer; Tycho was weak as a mathematician and theorist, but great as an observer — one of the greatest, and perhaps the greatest, of all time, relative of course to the equipment available in his day." Jeans had already described the growth of Copernicus' ideas and his difficulties in trying to fit the planetary observations with the old notion that the planets, being perfect bodies, had to move in circles. Then he described Tycho's superb observations, which became the basis for Kepler's laws, and finally listed the many contributions of Galileo in the fields of mechanics and physics. The chapter is dated 1452-1600.

No book on the history of astronomy or mathematics is complete without a chapter on the life and works of Sir Isaac Newton. Jeans devotes about 20 pages to this great scientist in the longest chapter in the book, which he calls, "The Century of Genius." Here we find listed also such men as Galileo, Descartes, and Hooke.

It is easy to see that Jeans thought that early science was hindered by religious beliefs during the first centuries of the Christian era. He also blamed Aristotle, as many people have done perhaps unjustly, for delaying science for a thousand years. Then he showed how the genius of Copernicus and Newton led the way for modern science, and named the many men (and a few women) who have contributed to the knowledge we have of the universe today. All branches of physical science are mentioned, but we notice the omission of a few important scientific developments. Photography, for example, is mentioned in several places, but there is no discussion of its discovery. Considering the importance of photography in modern astronomy, a few pages on its history and development would be valuable. And the discovery of photoelectricity and its application to astronomy are not included.

The book is readable and interesting and is a concise source for study of the development of physical science through the centuries.

C. M. HUFFER
Washburn Observatory

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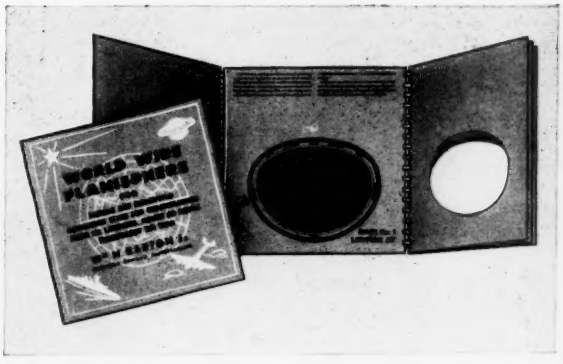

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GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

How to Build a Quartz Monochromator — IV

By Richard B. Dunn, *Harvard Observatory*

For the best contrast in solar work the filter should be made using the narrowest band possible — the thicker the final crystal, the better. The thinnest possible beginning crystal would give the widest separation of the final maxima, making the undesirable maxima easier to isolate. In our calculations we make use of the following table, originally determined by J. Macé de Lépinay in 1891, and available in **The Properties of Silica,** by Robert B. Sosman, Chemical Catalog Co., New York, 1927. The difference in the indices of the ordinary and extraordinary rays for quartz can be determined more accurately than the individual indices themselves. The table shows that temperature changes this difference.

Wave Length (angstroms)	10^3 ($n_e - n_o$) 0° C.	10^3 ($n_e - n_o$) 18° C.
3727.6	9.7141	9.6952
3820.43	9.6656	9.6467
3952.9	9.6042	9.5853
4101.74	9.5416	9.5227
4307.9	9.4671	9.4480
4861.33	9.3121	9.2928
5183.62	9.2439	9.2245
5892.9	9.1290	9.1093
6562.78	9.0493	9.0293
6883.8	9.0177	8.9975

The 0° C. values can be corrected, if desired, to values at other temperatures by using the correction given by Sosman: $-10^{-3}\ t\ (1 + t/900)(1.01 + 0.2\lambda^2)$, where the wave length, λ, is expressed in microns (one micron equals 10,000 angstroms), and the temperature, **t**, is in centigrade degrees. The values in the second column can be obtained from those in the first column by means of this correction.

The fundamental thickness for the monochromator crystals, as stated last month, is the wave length divided by the difference of the indices. Thus, for the hydrogen-alpha line, at 18° C.,

$$d_o = \frac{6562.8 \times 10^{-7}}{9.0293 \times 10^{-3}} = 0.072683 \text{ mm.}$$

The crystal thicknesses must then be integral multiples of this fundamental thickness, so that the transmission maxima will superimpose for parallel polaroids. Suppose that the largest crystal available allowed a plate some 46 or 47 millimeters thick; also that the thinnest crystal thought possible to produce would be somewhere around half a millimeter thick. Then the following series of thicknesses would be decided upon (remember that 25.4 mm. = 1 inch):

N	Thickness
10	0.727 mm.
20	1.454
40	2.907
80	5.815
160	11.629
320	23.259
640	46.517

Seven plates can be used, the thinnest 0.727 mm. and thickest 46.517 mm.

Evans shows that the adjacent maxima are at $\mathbf{N}\ \lambda/(\mathbf{N}+1)$ on one side of a given maximum and at $\mathbf{N}\lambda/(\mathbf{N}-1)$ on the other. The thinnest crystal, for which $\mathbf{N} = 10$ gives the widest separation of the maxima, therefore has its adjacent maxima at 5966 angstroms (6562.8 x 10/11) and at 7292 angstroms (6562.8 x 10/9). The first of these, on the violet side of our desired transmission, can be isolated easily with the Corning red filter. The infrared side, at wave length 7292, is beyond the visible light range and beyond the sensitizing of most photographic plates.

The width of the final band is determined by the thickest crystal, for which the adjacent minima are located at $\mathbf{N}\lambda/(\mathbf{N}+½)$ and $\mathbf{N}\lambda/(\mathbf{N}-½)$, respectively. For $\mathbf{N} = 640$, this gives 6557.7 angstroms (6562.8 x 640/640.5) and 6567.9 angstroms (6562.8 x 640/639.5), giving a width between the minima of about 10 angstroms. Actually, in practice the ef-

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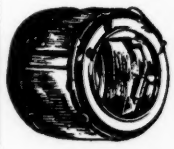

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fective width is about half of this, corresponding to the term "half width" used in discussions of filters.

The filter could be designed for two lines or even three or more depending on how close the desired wave lengths lie to the actual transmission band. Lyot managed to get eight lines by changing the temperature of the filter; these included two coronal lines and hydrogen-alpha. However, integer values can be selected sometimes that enable one just to change the glass filter to get the other lines. The combination we have referred to previously is $55d_0$ for H-alpha, 62 for the helium D_3 line, and $97\frac{1}{2}$ for the potassium K line, all at about 39° C. These are within the limits for isolating all three at one temperature, the limit being generally accepted as 1/20 the d_0 value. For multiline filters the violet line should be used for design tolerance because the fundamental thickness is smallest for it.

Another way of getting another line is to put a rotator between each two crystals, consisting of a mica "shim." The mica acts as a birefringent medium and corresponds to a few fundamental thicknesses. The shims can be made replaceable for different wave lengths, and in any filter they may be used for plates that are not finished exactly to a required thickness. Thus, each plate may be shimmed with mica until one of its transmission bands coincides exactly with the desired wave length. In using such shims, it is well to remember that the retardation a shim introduces in the red is not going to be the same as that it would introduce in the blue. Methods of splitting mica are described in Strong's **Procedures in Experimental Physics**, which, by the way, is a good book for the advanced amateur to have. Unfortunately, good optical mica is expensive.

As mentioned, the filter must be operated at a certain temperature, preferably higher than any natural conditions in the observatory. If this operating temperature were about 45° C., a change of about a degree would shift the transmission band almost an angstrom. In the **Astrophysical Journal, 100,** 1944, page 128, Pettit discusses these corrections and notes deviations from the computed values. In practice, the temperature correction and exact measures of the final thicknesses can be accounted for in the testing.

Our design temperature is 18° C., but testing may be done at room temperature with the following approximate correction (for the H-alpha region only) for a filter to be operated at 45° C.:

$$\Delta\lambda = 0.74\ (45-\mathbf{T}),$$

where **T** is the room temperature in degrees Centigrade. This correction will displace to the red the crosswire in the testing spectrograph. In other words, during testing at room temperature the transmission band will be shifted $\Delta\lambda$ to the red in the spectroscope. But when operating in the observatory, the heater will keep the transmission band on the H-alpha line. This correction takes into account the change in thickness of the quartz with temperature, but a more exact correction is given in Sosman's book, and must be used when designing a filter for two or more transmission bands simultaneously.

As has been mentioned, the filter could use crossed polaroids. The plates would not superimpose then, and nothing is to be gained, except that if one misses the thickness desired in a plate the polaroid can be crossed and grinding carried down to the next $\frac{1}{2}d_0$ instead of to the next d_0. The actual transmission band can be controlled quite nicely at the spectroscope. The crystals can also be heated up to temperature and then shimmed with mica, if necessary, as described above.

The method of calculating the field of the monochromator is beyond the scope of these articles. It is given in some detail in Evans' paper in the **Journal** of the Optical Society of America (see reference in April issue). The filter should be used in parallel light if possible. If placed before the focus in the converging beam some light will be lost, as much as 40 per cent at a focal ratio of f/8.5.

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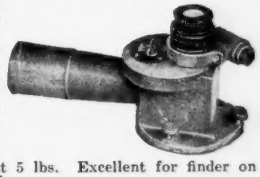

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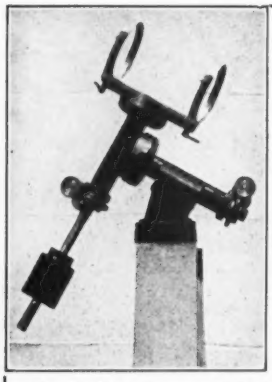

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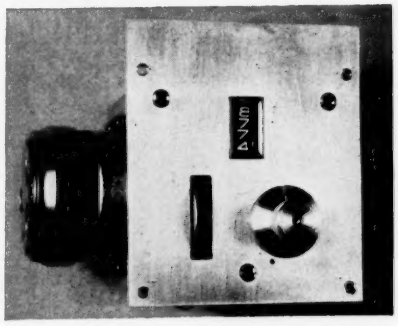

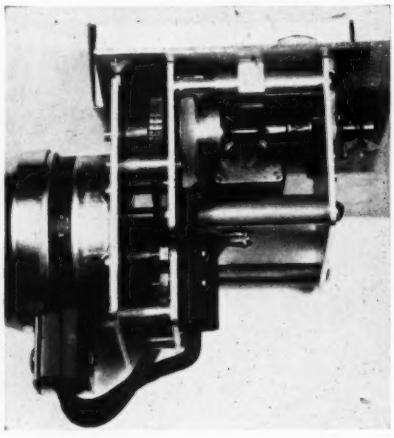

Above: The counter reading to four decimal places. Left, below: The motor and gear train assembly.

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

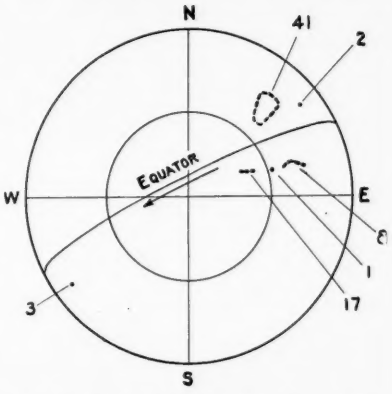
VISUAL OBSERVING PROGRAMS FOR AMATEURS — XVI

Observing the Sun — (continued)

We come now to the question of orienting ourselves. If you use a refractor with a Herschel wedge, there is one reflection, and therefore the image will be upright with the north pole of the sun uppermost and the south lowermost. The preceding edge will be to the left (which can be checked by letting the sun drift across the field of view) and the following edge to the right. However, the sun may be tipped at a considerable angle to the vertical, especially if it is low in the eastern or western sky. To determine the east and west line you need a crosshair, spine, or reticle in your eyepiece. I have an eyepiece equipped with a reticle which I use for this purpose each day, and then I remove it and replace it by an eyepiece not so equipped before I count the sunspots. This is because the reticle gets dusty so that I see many spurious spots when using it; if you tap on the prism housing you will note that spots move with the sun — anything spurious will not. Simple crosswires or a spine would not suffer from this defect. A spine is made of a needle or a fine wire projecting from the edge to the center of the field, and it is rotatable.

What I do is center the crossed lines of the reticle on a sunspot. Then I allow the spot to drift to the left, and after a few seconds I rotate the eyepiece and its attached reticle so that one line of the reticle again bisects the spot. This line then must lie along the east and west drift line of the sun. I now move the telescope as a whole so that the reticle is centered on the sun and makes a cross over the face of the sun showing east and west and north and south lines.

In my daily notebook I already have a blank drawing of the sun consisting of a circle, to represent the sun, a second circle inside it of half diameter, to represent the central zone, and two lines at right angles through the center to represent E-W and N-S lines, as on the accompanying illustration. Note that the center zone represents a circle on the sun 60 degrees in diameter with its center at the subzenithal point. (It is thought that solar activities within this zone, which faces toward the earth, may affect us more than activities occurring elsewhere on the sun's disk.) On my blank drawing I make marks, usually dots for small groups and lines for elongated groups, showing all the groups on the sun in their correct locations as compared to the reticle lines, and then I am prepared to count the sunspots.



The author's drawing of the sun (40x with Herschel wedge) at 15:10 UT, April 15, 1951. The numbers show how many spots comprised each group. The group of 17 spots had just entered the central 60° zone, and would require four or five days to move through it.

There is one oddity about marking east and west on the sketch of the sun. West is considered as the preceding limb, east the following. If you stand looking south at midday, geographic west is on your right hand and so is the preceding limb of the sun, hence the preceding limb of the sun is called its west limb, but this is the reverse of the way a globe of the earth would be marked. Even if viewed from the Southern Hemisphere this anomaly still exists. From two or three days of observing and of making sketches, it will become apparent that the rotation of the sun is such that it brings spots around from the east side to the west, that is, from the following toward the preceding limb. As the synodic period of rotation of the sun on its axis is about four weeks, it will take 14 days for a large spot to move from the east to the west limb, and seven days from limb to meridian. Since the central zone, described above, sub-

Neal J. Heines, chairman of the Solar Division of the AAVSO, and the apparatus he uses for daily sunspot counts.

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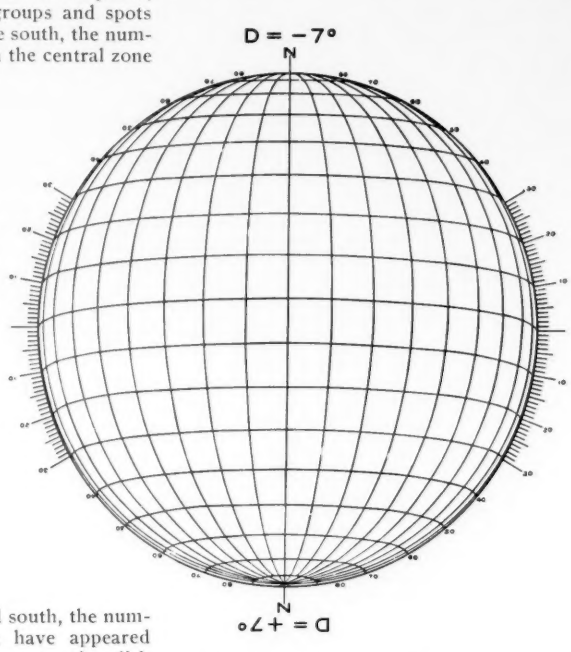
tends 60 degrees along the equator (less elsewhere) a spot near the sun's equator will cross the central zone in about 4½ days.

After making my rough sketch of today's sunspots, I remove the dusty reticle and insert the eyepiece without a reticle. I count the spots in each group, drawing an arrow on the sketch with its point at the group, and at its feathered end I show the number of spots in the group, together with any comments, such as "this group shows pores," or "wisps," or is "small" or "large," or "has changed materially since yesterday," or "shows color," or is a "veiled group."

We are finished now with our sunspot observations, but before we can enter them on our report form there is one more step to take. The E-W line on the sketch corresponds only to the sun's east-west drift through the telescope field. Where is the sun's equator? There are eight sketches of the sun's co-ordinates that are called Stonyhurst disks. Each represents a degree of tilt of the sun's axis of rotation to the observer's view. By using information from the **American Ephemeris**, for physical observations of the sun, the position angle of the sun's axis can be ascertained, as well as the heliographic latitude and longitude of the center of its disk. The first two are nearly the same for a particular date every year, and the selection of a particular Stonyhurst disk may thus be made by reference to a standard list of dates. By consulting the appropriate Stonyhurst disk, the sun's equator can be plotted on the daily sketch.

The AAVSO Solar Division has issued Stonyhurst disks of smaller size with its pamphlet describing the classification of sunspots. They are classified from the very small **A** groups through the largest and most active **F** groups to the decadent **H** and **J** groups.

With our sketch all duly oriented and annotated, and with the sun's equator drawn in, we are in a position to fill in our "Sunspot Report" as furnished by the Solar Division. From the sketch we can secure all the information that is required, such as the number of groups and spots north of the equator, those south, the number of groups and spots in the central zone divided between north and south, the number of new groups that have appeared since yesterday and where on the disk they have appeared, and the number that have disappeared, including whether these passed over the western limb or merely faded away.



One of the Stonyhurst disks used for determining solar co-ordinates. This represents the maximum latitude inclination of 7¼°, which occurs early in March and September each year. The other Stonyhurst disks are from 0° to 6° inclinations. Published by Casella & Co., London; courtesy AAVSO Solar Division.

There seems to be a certain peculiarity about observing the sun. I believe all observers experience it. When I first started the work, just after sunspot minimum in 1944, there were days when I did not see any sunspots, although later I found that others had seen some. Though I had been doing variable star work for a dozen years, my eye apparently needed training for solar work. To a lesser extent this condition exists also when I make each daily observation. The large groups are evident at a glance, but the longer I look, up to say several minutes, the more acute my eyesight seems to become, and several more small groups or single spots may be discovered. It is so odd to become aware suddenly of a distinct spot on the sun that I have previously overlooked for some minutes, that I often wonder if it can have developed in the few moments since I began observing, but as others have this same difficulty I am sure it is an idiosyncrasy of the human eye.

Search the sun not once, but several times each time you observe. Search both near the equator and in higher latitudes. Search the eastern limb for spots which are just rising over the sun's edge. Perhaps once or twice a month I discover such a spot at the last minute before ceasing observing, which had previously been undetected. Don't neglect the western limb. Usually there you will find the last glimpses of groups with which you have been well acquainted as they traversed the sun's disk, but sometimes a new large group will form there just before it disappears over the limb.

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Cambridge 38, Massachusetts

VARIABLE STAR MAXIMA

July 2, R Ursae Majoris, 7.6, 103769; 5, T Cephei, 5.8, 210868; 7, T Centauri, 6.1, 133633; 9, S Coronae Borealis, 7.5, 151731; 12, R Normae, 7.2, 152849; 23, U Cygni, 7.6, 201647; 29, S Canis Minoris, 7.5, 072708. August 3, R Octantis, 7.9, 055686; 3, T Ursae Majoris, 7.9, 123160; 4, R Hydrae, 4.6, 132422; 6, T Cassiopeiae, 7.8, 001755.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the predicted magnitude, and the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern).

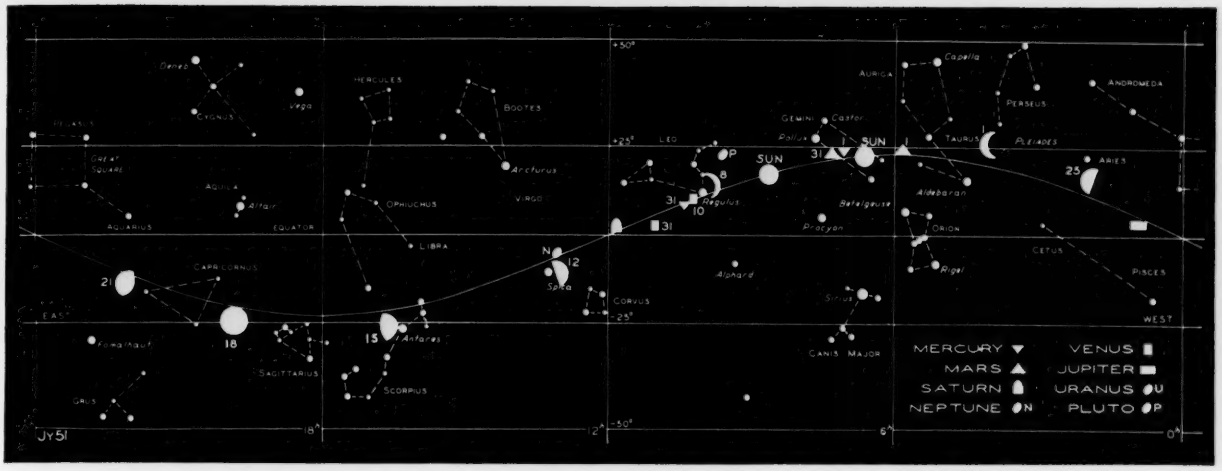
MINIMA OF ALGOL

July 3, 11:56; 6, 8:45; 9, 5:33; 12, 2:22; 14, 23:10; 17, 19:59; 20, 16:48; 23, 13:36; 26, 10:25; 29, 7:13. August 1, 4:02; 4, 0:51; 6, 21:39.

These predictions are geocentric (corrected for the equation of light), based on observations made in 1947. See **Sky and Telescope**, Vol. VII, page 260, August, 1948, for further explanation.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, and the result is your standard time on the day preceding the Greenwich date shown.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury appears in the evening sky and may be viewed for most of July. The first week finds the elusive planet, shining at magnitude −1, moving away from the sun but setting less than one hour after it. Greatest elongation is not attained till August 3rd, in a position 27° 19′ east of the sun, but then the planet will be nearly two magnitudes fainter than a month previous.

Venus attracts most attention in the period from eastern to western elongation, when it is nearest to the earth and goes through its greatest variations of phase and apparent size. The halfway point from eastern elongation to conjunction with the sun is attained on July 29th, the planet appearing at greatest brilliance, of stellar magnitude −4.2. During July the apparent diameter of Venus increases from 25 to 39 seconds of arc, with the illuminated portion decreasing to 26 per cent on the 29th. On that date Venus sets only 1½ hours after the sun, for the planet is south of the sun and poorly placed for observers in northern latitudes. On the evening of July 6-7, Venus will pass about 10′ south of the star Regulus. The following evening the crescent moon will be to the west of the pair.

Mars remains near the sun in the morning sky. On July 31st, the planet rises 1½ hours before the sun and may be glimpsed with slight optical aid.

Jupiter arrives at western quadrature with the sun on July 5th, appearing above the east point shortly before midnight. Of magnitude −2.0, the planet cannot be mistaken, for it far outshines all other objects near it.

Saturn is visible in the western sky for three hours after sunset in mid-July. This month will be the last opportunity for observation in the evening sky this year. Not conspicuous, appearing at +1.3 magnitude to the east of Beta Virginis, Saturn as viewed in a telescope presents its rings inclined 2°.0 to our line of sight.

Uranus enters the morning sky on July 2nd, passing conjunction with the sun, and hence not visible.

Neptune may be found during the evening hours located about ½° west of Theta Virginis. It appears as a star of the 8th magnitude and is slowly moving eastward toward Theta.

E. O.

PHASES OF THE MOON

New moon	July 4,	7:48
First quarter	July 12,	4:56
Full moon	July 18,	19:17
Last quarter	July 25,	18:59
New moon	August 2,	22:39

	July	Distance	Diameter
Apogee	3, 4h	252,600 mi.	29′ 24″
Perigee	17, 23h	222,600 mi.	33′ 21″
Apogee	30, 12h	252,200 mi.	29′ 26″

JUPITER'S SATELLITES

JUPITER, at quadrature on the 5th of July, attains a position of prominence in the morning sky. This is one of the "seasons" described by the writer on pages 44-46 of **Sky and Telescope** for December, 1950, for simultaneous disappearances among the first three satellites. In Fig. 1 of that article, the direction of **A** coincides with that of the sun at 0°. By July 13th, the clockwise rotation of **A**, indicated in Fig. 9, has amounted to 180°, so that **II** and **III** undergo simultaneous eclipse while the shadow of **I** is in transit. A little earlier there is simultaneous occultation and physical transit. The dates of mutual disappearance of all three are July 2, 9, and 16. The sequences of events for those days, reproduced from the **American Ephemeris,** are printed below the chart of satellite configurations. On July 18th and 25th, **I** and **II** disappear while **III** is near greatest elongation west. Because the planet is at quadrature, there will be a maximum lag of physical transit behind shadow transit of all three moons, and this is the best opportunity to see both a moon and its shadow at the same time.

The orbits of the satellites have opened up so much now that for the next three years **IV** will never disappear from view. Its last occultations and transits came in May. Shadow transits and eclipses have continued, however, but there will be no more after July 15th. On that date, for 19 minutes beginning at 6:53 UT, the final shadow transit occurs, and it is visible generally throughout the United States except for the Pacific time belt. The last eclipse, on July 6th, takes place below the horizon for the United States.

PAUL W. STEVENS

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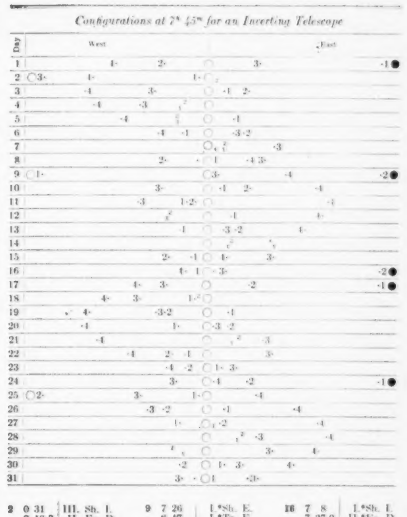
Jupiter's four bright moons have the positions shown below for the Universal time given. The motion of each satellite is from the dot to the number designating it. Transits of satellites over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. All events for July 2, 9, and 16, are given at the foot of the chart. Asterisks indicate phenomena visible at Washington, D. C. Ec denotes eclipse; Oc, occultation; Tr, transit of the satellite; Sh, transit of the shadow; I, immersion; E, emersion; D, disappearance; R, reappearance. The chart is from the American Ephemeris and Nautical Almanac.

Configurations at 2h 45m for an Inverting Telescope



2	0 31	III. Sh. I.	9	7 26	I.*Sh. E.	16	7 8	I.*Sh. I.
	2 18.3	II. Ec D.		8 42	I.*Tr. E.		7 27.0	II.*Ec D.
	3 20	I. Sh. I.		10 17	II. Oc. R.		8 29	I.*Tr. I.
	3 25	III. Sh. E.		10 20	III. Tr. I.		8 33	III.*Sh. I.
	4 43	I. Tr. I.		12 51	III. Tr. E.		9 20	I.*Sh. E.
	5 33	I. Sh. E.		4 33	III. Sh. I.		10 39	I. Tr. E.
	6 18	III.*Tr. I.		4 52.6	II. Ec D.		11 25	III. Sh. E.
	6 54	I.*Tr. E.		5 14	I.*Sh. I.		12 49	II. Oc. R.
	7 43	II.*Oc. R.		6 37	I.*Tr. I.		14 17	III. Tr. I.
	8 52	III.*Tr. E.		7 25	III.*Sh. E.		16 45	III. Tr. E.

OCCULTATION PREDICTIONS

Information on the occultation of Delta Piscium on July 23-24 was published in the June issue, page 204.

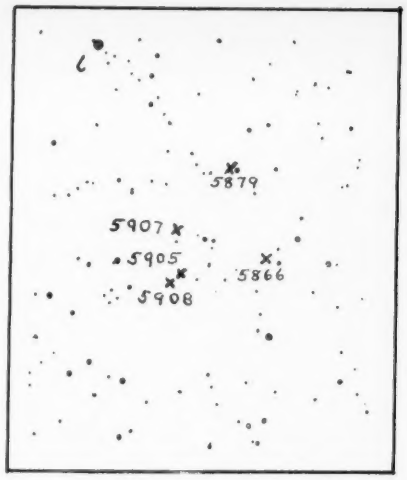
DEEP-SKY WONDERS

A NUMBER of amateurs have already sent in their observations on the visibility of the three galaxies listed in the May **Sky and Telescope,** and this month we list five more in Draco. When enough reports have been obtained, we should have some interesting conclusions for our readers.

Please observe the following objects as suggested in May, and send the results to the writer at 811 N. Fifth, St. Charles, Mo. NGC 5866 is Messier 102.

This may be a good place to reprint the Herschel nebula classification: I, bright; II, faint; III, very faint; IV, planetary; V, very large; VI, very compressed and rich clusters; VII, compressed clusters, small and large stars; VIII, coarse, scattered clusters. The class number is indicated in the second column of the table by the Arabic superscript at the end of the Herschel number.

WALTER SCOTT HOUSTON



Iota Draconis is in the northeast (upper left) corner. Scale is 1° to 1 centimeter. The limiting magnitude is 9.

Designation		R.A.	Dec.	Mag.	Size	Type
NGC 5866	215[1]	$15^h\ 05^m.1$	+55° 57′	11.5	3′.0 x 1′.0	Sa
NGC 5879	757[2]	$15^h\ 08^m.4$	+57° 12′	12.1	3′.3 x 1′.3	Sb
NGC 5905	758[2]	$15^h\ 14^m.1$	+55° 42′	13.1	.....	..
NGC 5907	759[2]	$15^h\ 14^m.6$	+56° 31′	11.8	11′.0 x 0′.6	Sc
NGC 5908	760[2]	$15^h\ 15^m.4$	+55° 36′	13.0	.....	..

METEORS IN JULY

July opens the half of the year when meteors are twice as numerous as during the previous six months. The first major shower, the Delta Aquarids, is at maximum on July 28th and visible to a lesser extent for a week preceding and after this date. Rates from 20 to 30 meteors are usual after midnight; many trained and bright meteors may be expected as well. The moon will be past last quarter so conditions are favorable. The first signs of the Perseid shower appear at this time, but these meteors do not become numerous till August 7th. E. O.

PREDICTIONS OF BRIGHT ASTEROID POSITIONS

No. 8	Flora		Mag. 8.7	
	h	m	°	′
July 3	21	02.4	−18	18
13	20	56.6	−19	20
23	20	48.2	−20	35
Aug. 2	20	38.2	−21	53
12	20	27.9	−23	05
22	20	18.9	−24	02

No. 349	Dembowska		Mag. 9.5	
	h	m	°	′
July 23	22	18.1	−23	30
Aug. 2	22	11.9	−24	18
12	22	04.0	−25	01
22	21	55.2	−25	35
Sept. 1	21	46.5	−25	55
11	21	38.9	−25	57

No. 19	Fortuna		Mag. 9.7	
	h	m	°	′
July 3	20	24.0	−16	45
13	20	15.8	−17	06
23	20	06.2	−17	33
Aug. 2	19	56.4	−18	02
12	19	47.5	−18	30
22	19	40.6	−18	54

The above are predicted positions in right ascension and declination for the epoch 1951.0, for 0^h Universal time. The magnitude is that expected at opposition. In each case the motion of the asteroid is retrograde.

MAY SUNSPOTS

A large sunspot group, which passed the central meridian of the sun for the third time on May 16th, was then observed by Herbert Luft, of Elmhurst, N. Y., to have a total length of over 200,000 kilometers. He reports that the group could be seen with the unaided (but protected) eye.

Neal Heines, chairman of the AAVSO Solar Division, notes that in June this group returned for the fourth time. It is expected that this sunspot minimum will be short, perhaps similar to those between the maxima of 1830 and 1837, and 1761 and 1769.

LEON CAMPBELL

(Continued from page 210)

liaison work between the professional and the amateur. More than anyone since the time of Simon Newcomb, he knew how to bridge this gap, sharing his technical skill and guiding by example. While none of his five children has become an astronomer, there are numerous astronomical observers throughout the world who gained their initial start under his guidance or inspiration.

Planetarium Notes

BALTIMORE: *Davis Planetarium.* Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., Mulberry 2370.
SCHEDULE: 4 p.m. Monday, Wednesday, and Friday; Thursday evening, 7:45, 8:30, 9:30 p.m. Admission free. Spitz projector. Director, Paul S. Watson.

BOSTON: *Little Planetarium.* Boston Museum of Science, Science Park, Boston 14, Mass. Richmond 2-1410.
SCHEDULE: Tuesday through Friday, 3 and 4 p.m.; Saturday, 11 a.m., 2, 3, and 4 p.m.; Sunday, 2, 3, and 4 p.m. Spitz projector. In charge, John Patterson.

BUFFALO: *Buffalo Museum of Science Planetarium.* Humboldt Parkway, Buffalo, N. Y., GR-4100.
SCHEDULE: Sundays, 2:00 to 5:30 p.m. Admission free. Spitz projector. For special lectures address Elsworth Jaeger, director of education.

CHAPEL HILL: *Morehead Planetarium.* University of North Carolina, Chapel Hill, N.C.
SCHEDULE: Daily at 8:30 p.m.; Saturday and Sunday at 3:00 p.m. Zeiss projector. Manager, A. F. Jenzano.

CHICAGO: *Adler Planetarium.* 900 E. Achsah Bond Drive, Chicago 5, Ill., Wabash 1428.
SCHEDULE: Mondays through Saturdays, 11 a.m. and 3 p.m.; Sundays, 2:30 and 3:30 p.m. Zeiss projector. Director, Wagner Schlesinger.

KANSAS CITY: *Kansas City Museum Planetarium.* 3218 Gladstone Blvd., Kansas City 1, Mo., Chestnut 2215.
SCHEDULE: Wednesday and Saturday, 3:30 p.m.; Sunday, 3:00 and 5:00 p.m. Spitz projector. Director, Charles G. Wilder.

LOS ANGELES: *Griffith Observatory and Planetarium.* Griffith Park, P. O. Box 9787, Los Feliz Station, Los Angeles 27, Calif., Olympia 1191.
SCHEDULE: Wednesday and Thursday at 8:30 p.m.; Friday, Saturday, and Sunday at 3 and 8:30 p.m.; extra show on Sunday at 4:15 p.m. Zeiss projector. Director, Dinsmore Alter.

NEW YORK CITY: *Hayden Planetarium.* 81st St. and Central Park West, New York 24, N. Y., Trafalgar 3-1300.
SCHEDULE: Mondays through Fridays, 2, 3:30, and 8:30 p.m.; Saturdays, 11 a.m., 2, 3, 4, 5, and 8:30 p.m.; Sundays and holidays, 2, 3, 4, 5, and 8:30 p.m.; Wednesdays and Fridays, 11 a.m., for school groups. Zeiss projector. Chairman, Robert R. Coles.

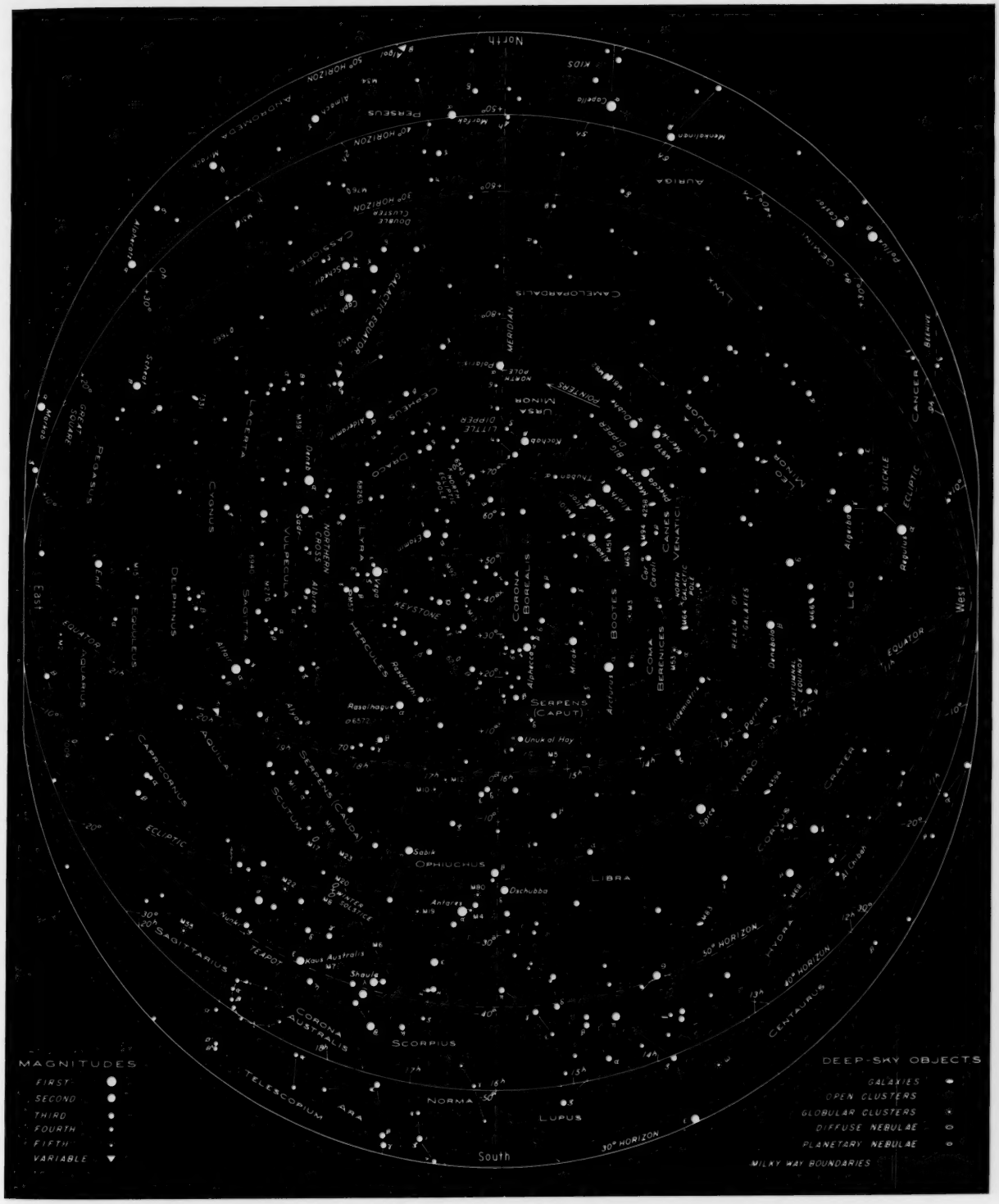
PHILADELPHIA: *Fels Planetarium.* Franklin Institute, 20th St. at Benjamin Franklin Parkway, Philadelphia 3, Pa., Locust 4-3600.
SCHEDULE: Tuesdays through Sundays, 3 p.m.; Saturdays, 11 a.m.; Saturdays, Sundays, and holidays, 2 p.m.; Wednesdays, Fridays, and Saturdays, 8:30 p.m. Zeiss projector. Director, I. M. Levitt.

PITTSBURGH: *Buhl Planetarium and Institute of Popular Science.* Federal and West Ohio Sts., Pittsburgh 12, Pa., Fairfax 4300.
SCHEDULE: Mondays through Saturdays, 2:15 and 8:30 p.m.; Sundays and holidays, 2:15, 3:15 and 8:30 p.m. Zeiss projector. Director, Arthur L. Draper.

PORTLAND, ORE.: *Oregon Museum of Science and Industry Planetarium.* 908 N.E. Hassalo St., Portland 12, Ore., East 3807.
SCHEDULE: Saturday, Sunday, and Wednesday, 4:00 p.m.; Tuesday, Thursday, and Friday, 8:00 p.m.; Saturday show for children only, 10:30 a.m. Spitz projector. Director, Stanley H. Shirk.

SPRINGFIELD, MASS.: *Seymour Planetarium.* Museum of Natural History, Springfield 5, Mass.
SCHEDULE: Tuesdays, Thursdays, and Saturdays at 3 p.m.; Tuesday evenings at 8 p.m.; special star stories for children on Saturdays at 2 p.m. Admission free. Korkosz projector. Director, Frank D. Korkosz.

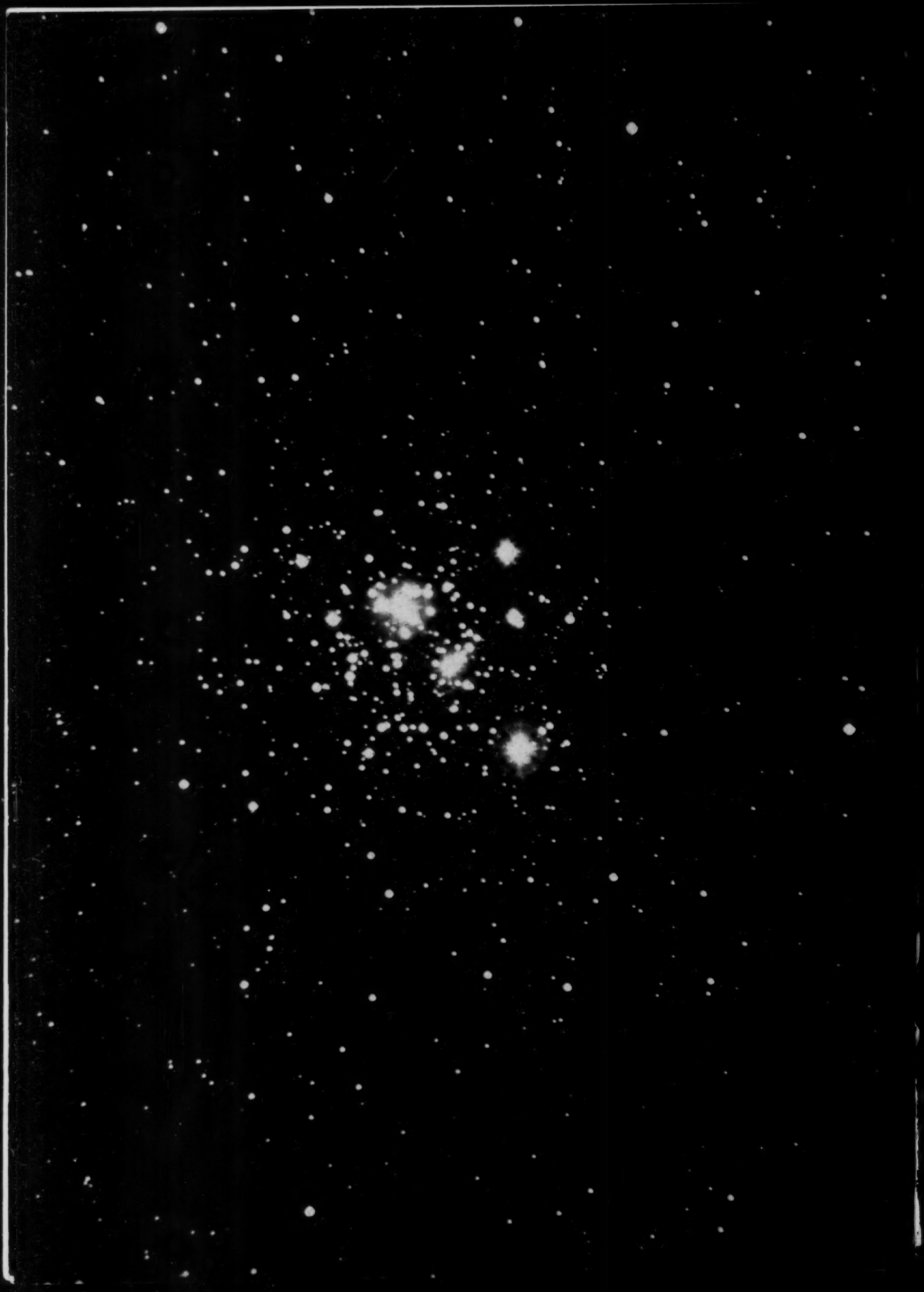
STAMFORD: *Stamford Museum Planetarium.* Courtland Park, Stamford, Conn.
SCHEDULE: Sunday, 4:15 p.m. Special showings on request. Admission free. Spitz projector. Director, Robert E. Cox.



The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of July, respectively.

STARS FOR JULY

WHEN vacation trips are made more enjoyable by the opportunity to spend time under July's evening skies, populated by such brilliant groups as Scorpius and Sagittarius in the south, Boötes, Corona, Hercules, Lyra, and Cygnus farther north, take time to identify some lesser-known constellations.

Draco extends his tail between the two Dippers, his body curls part way around the bowl of the Little Dipper, and his head reaches southward toward Hercules.

Hercules and Draco have many riches for the telescope enthusiast. The great globular cluster, M13, just visible to the naked eye, is easily resolved with an 8-inch telescope under good conditions. Not far away is another globular, M92. Alpha Herculis is a really orange star, which shows double in a telescope, the fainter component listed as green by Norton. Kappa Herculis is an easy double; and Delta Herculis is an optical pair. Many stars in Draco are double, including Epsilon and Eta; and near the north pole of the ecliptic is NGC 6543, a fine planetary nebula. Deep-Sky Wonders this month lists five galaxies near Iota Draconis.